General Geology of northern Gunung Semanggol, Bukit Merah, Taiping

with emphasis on

Tectono-Stratigraphic Evolution of Semanggol Formation

by

Nur Farahin Usop

13579

Dissertation submitted in partial fulfilment of

the requirement for the

Bachelor of Technology (Hons)

(Petroleum Geoscience)

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Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

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(MD YAZID B MANSOR)

Universiti Teknologi PETRONAS

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Perak Darul Ridzuan

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(NUR FARAHIN USOP)

ACKNOWLEDGEMENT

I would like to thank God Almighty Allah S.W.T for His blessings that I am able to complete this Final Year Project and thus finishing this report. Other than that, both of my parents have been giving me constant support and words of encouragement and I thank them for that.

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ABSTRACT

Previous researches of northwest Peninsular Malaysia have classified Gunung Semanggol as part of the Semanggol Formation that extends from north and south Kedah. The study presented in this paper aims to investigate the geological outcrops along the west and east face of the northern Gunung Semanggol. Data recorded during the research is used to conceptualise a sedimentary facies model, depositional settings and tectono-stratigraphic model. The methods used are geological fieldwork and laboratory works including thin section and petrography analysis. The results show that the outcrops exhibit fining upward sequence of bedded chert, and sandstone interbedded with shale, as well as some siltstone. It is postulated that the northern Gunung Semanggol was once deposited in deep marine settings that lead to deposition of bedded chert, followed by deposition of turbidite materials. The age of the northern Gunung Semanggol formation is suggested to be Permo-Triassic. The data presented in this paper are valuable in understanding the geological link between outcrops of the Semanggol Formation. It is recommended that other aspects such as biostratigraphy and geochemistry to be included in the future to gain accurate distinction between Permian and Triassic rocks formation of the northern Gunung Semanggol and the Semanggol Formation exclusively.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Gunung Semanggol is located in Kerian district, north of Perak Darul Ridzuan. Gunung Semanggol comprised of northern and southern Gunung Semanggol. The study area is located at latitude and longitude 4^0 57’ 40.5’’ N, 100^0 39’ 5.38’’ E until 4^0 59’ 56.66’’ N, 100^0 39’ 22.17’’ E. The Semanggol range is located 13 km northwest of Taiping. The length of the transect is approximately 4 km. This project concentrates on the west and east face of northern Gunung Semanggol which covers an area of 5.25 km^2.

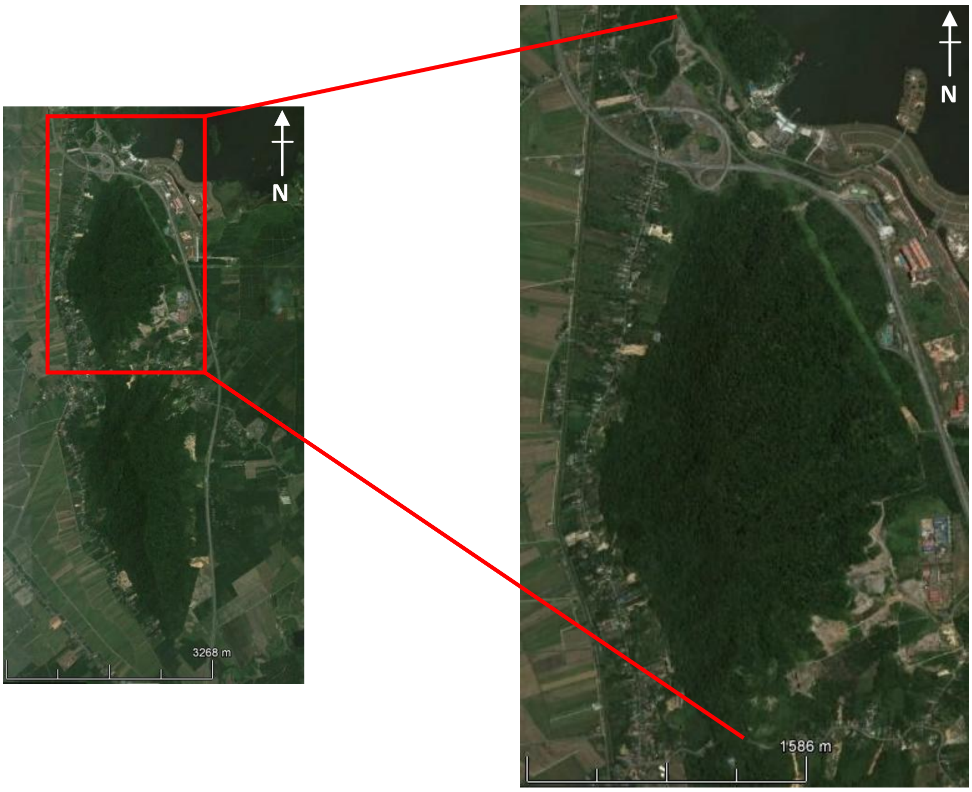


Figure 1.1: Aerial photograph showing Gunung Semanggol (left) and northern Gunung Semanggol (right)

Gunung Semanggol is a part of Semanggol Formation that stretches from the northern border of Kedah southwards to north Perak. The formation is named after Gunung Semanggol, although no formal description of the type section is given. The name is then adopted by other authors to describe Triassic sedimentary rocks covering north Kedah, south Kedah and north Perak. Despite being an informal unit, the name is used extensively in the geological publications of Malaysia.

The general drainage on the west face of the Semanggol range is altered by Terusan Selinsing, which acts as irrigation canals used for paddy fields, covering Kampung Tebuk Matau and Kampung Matang Pasir. Sungai Kurau and Sungai Air Kuning serve as tributaries on the west and east face of the northern Gunung Semanggol, respectively. Kampung Balek Bukit and Kampung Kubu Gajah are located on the south and north of the northern Gunung Semanggol, respectively.

Other than previous studies, no extensive geological researches have been done on the geology of Gunung Semanggol and its relation to Semanggol Formation. It may be incomplete or unpublished. Most of the researches concentrate to Semanggol Formation at north and south Kedah. Bukit Merah Lake is not included in this study.

1.2 PROBLEM STATEMENT

Throughout this project, issues or research questions that are hoped to be answered by the end of this project are what is the geology of the northern Gunung Semanggol is? What were the sedimentary processes that lead to the deposition of the sediments? How tectonic events can be related to the deposition of sediment, and what is the relationship between rock formations?

1.3 OBJECTIVES

The aims of this project are:

1. To conduct and construct field sedimentary logs, generate geological map and geological cross section of the study area.
2. To describe the sedimentological process that occurred during the deposition of sediments.
3. To explain the effects of regional tectonic events on the lithostratigraphy of the rock formations and their relationship.

1.4 SCOPE OF STUDY

The scope of this project includes geological mapping techniques, sedimentology and tectono-stratigraphy. During geological fieldwork, observation and measurement of study area is done. Data such as strike, dip, rock types, and photos are taken. Rock sample collection is done for further investigation in the laboratory.

In sedimentology and stratigraphy aspect, the sedimentary processes and environment change are discussed. This information is used to describe the depositional setting of the northern Gunung Semanggol. Other than that, the vertical rock succession is determined, from the oldest to the youngest rocks. Tectonic events are recorded in the sediments that are deposited at the same time. The rock formations can be correlated in terms of their connection to tectonic events. Evolution of the northern Gunung Semanggol can be understood by building a tectono-stratigraphic model which explains tectonic events that occurred and how these tectonic events contribute to the deposition of the sediments.

CHAPTER 2

LITERATURE REVIEW

2.1 THE SEMANGGOL FORMATION

Semanggol Formation is named by Alexander (1959) for defining Middle Triassic argillaceous-arenaceous rocks at Gunung Semanggol, north Perak. The usage of the name is informal as there was no statement to designate a formal unit, or description of the type area (Burton, 1988). Burton (1970) and Courtier (1974) have extended the formation to north and south Kedah. This was reported by Courtier (1974) during his study of Kulim area as he stated that “the beds bear a marked lithological resemblance to those which form the Semanggol ridge in north Perak”. Despite being an informal unit, this name has been used extensively in the publication of the geology of Malaysia.

Jasin (1997) proposed that the Semanggol Formation was probably deposited in the same basin which was later separated into three areas by wrench fault. The three separate fault-displaced areas are in Padang Terap (north Kedah), Kulim-Baling (south Kedah) and Gunung Semanggol (north Perak) (Jasin & Harun, 2007; Jasin, 2008; Hutchison & Tan, 2009). Foo (1990) stated that the formation at Gunung Semanggol area does not represent a complete succession of the Semanggol Formation, due to absence of the top and bottom of the formation. The contacts with adjacent lithostratigraphic units are either faulted or unexposed (Hutchison & Tan, 2009). Foo agreed that the base of Semanggol Formation was unable to be identified and the top of formation is eroded. According to Burton (1988), the Semanggol Formation extends from northern Kedah into southern Thailand where it has been referred to as Na Thawi Formation, and spread farther into northern Thailand (Chieng Rai and Lampang) and Burma.

2.2 REGIONAL SETTING

The Southeast Asia region is comprised of complex tectonic collage of allochthonous continental fragment (Metcalfe, 1998; Spiller & Metcalfe, 1995). They drifted from their original location by various plate tectonic mechanisms and later have been amalgamated and accreted into Southeast Asia. Sibumasu block, which was located at eastern part of Pangaea, drifted northwards into low latitudes and at the same time the Palaeo-Tethys Ocean was widening.

The Palaeo-Tethys oceanic plate was subducting beneath the East Malaya block. This stage is halted at about Middle Triassic when Sibumasu block collided with Indochina-East Malaya block (Ridd, 2013). During Late Triassic, crustal shortening continued and a foredeep basin in front of accretionary complex was developed. Metcalfe (2000) had similar suggestion when he reported that the collision between Sibumasu and Indochina-East Malaya was an indication that the upper part of the Semanggol Formation was in foredeep basin and partly over accretionary complex. Remnants of this ocean were subsequently thrusted westwards over the Sibumasu block. The westwards thrusting would provide ample supply of eroded chert and clastics sediments into the Semanggol basin (Hutchison & Tan, 2009). Sashida et al. (1995) suggested that the accretionary wedges were the source areas for turbidites in the rhythmite member.

Sibumasu block and East Malaya block are in contact with the Bentong-Raub suture zone, extending from Uttaradit-Nan suture in Thailand to Lalang line in Sumatra (Sashida, Adachi, Igo, Koike & Amnan, 1995; Cocks, Fortey & Lee, 2004). After the collision between Sibumasu and Indochina-East Malaya block, the Late Triassic Indosinian orogeny took place (The Malaysian and Thai Working Groups, 2006). The Bentong-Raub suture zone has been interpreted to represent the former Palaeo-Tethys Ocean, which once separated Sibumasu and East Malaya block (Spiller & Metcalfe, 1995; Metcalfe, 2000).

Table 2.1: Palaeozoic and Mesozoic events and their age in East and SE Asia (Metcalfe, 1998)

Age	Process
Early Devonian	Rifting of South China,North China, Indochina,Tarim and Qaidam from Gondwanaland
Middle/Late Devonian	Initial spreading of the Palaeo-Tethys Ocean
Late Devonian to Early Carboniferous	Amalgamation of South China, Indochina and East Malaya to form Cathaysialand
Late Early Permian	Rifting of Sibumasu from Gondwanaland
Late Permian to Triassic	Collision and suturing of Sibumasu to Indochina
Late Triassic	Full closure of Palaeo-Tehys Ocean and formation of Indosinian orogeny complex

2.3 GEOLOGICAL SETTING

In 1973, Burton divided the formation into three members namely chert, rhythmite and conglomerate members. However, the term member rank was dropped and the term unit is used. Burton (1970) described that the Semanggol Formation at Baling area consists of rapidly alternating of shale, siltstone, and sandstone with a few bands of chert. Burton (1973) suggested that the Semanggol Formation young towards the east or southeast In the Gunung Semanggol area, Foo (1990) reported that the rocks consist of two dominant facies, a rudaceous-arenaceous facies of intraformational conglomerate and sandstone, and an argillo-arenaceous facies of rhythmically bedded sandstone and shale.

Hutchison and Tan (2009) described the geologic setting of each of the unit. Siliceous deposits of Palaeozoic and Mesozoic rocks commonly occur as cherts and siliceous mudstones (Jasin, Harun & Hassan, 2003). The oldest chert unit of Semanggol Formation consists of chert, mudstone, shale and sandstone. Chert bands form ridges and form positive topographic feature in the low-lying country of Semanggol Formation (Burton, 1988). Due to its resistance to weathering, cherts are proportionately much more abundant than other clastic rocks. Cherts are present in every sedimentary sequence in, indicating that they might be localised occurrences (Courtier, 1974).

Seven lithofacies have been identified that represent the chert unit in Kuala Ketil area (Jasin, Harun, & Said, 2005a; Jasin, Harun, Said & Saad, 2005b; Jasin & Harun, 2007; Harun et al., 2009). Ribbon-bedded chert within the Semanggol Formation have yielded Permian and Triassic radiolarians (Metcalfe, 2000). However, Hutchison and Tan (2009) reported that the contact between Permian and Triassic has not been discovered though they are in close stratigraphic proximity. Radiolarian biostratigraphy proved that chert member is the oldest unit of the Semanggol Formation, and only the Middle and Late Triassic chert is in lateral deposition with rhythmite and conglomerate member.

The middle unit, rhythmite unit is composed of alternating beds of sandstone and mudstone, or shale. Occasional beds or lenses of conglomerate can be seen. Courtier (1974) reported in his studies that the rhythmite member at Kulim area is predominantly arenaceous. On the other hand, geological studies of Baling area by Burton (1988) revealed that the area is made up of argillaceous rocks. Scour and ripple marks can be seen on the top of sandstone beds (The Malaysian and Thai Working Groups, 2006).

Jasin (1994) explained that the rhythmite unit consists of turbiditic sandstone interbeds with mudstone. The sandstone may grade up into siltstone or shale. One distinction from previous researches is that the Malaysian and Thai Working Groups (2006) have separated the chert unit from the other two units. The rhythmite unit of Semanggol Formation is the same as Na Thawi Formation in Thailand. The sandstone exhibit graded bedding is overlain by shale or mudstone.

The uppermost unit, the conglomerate unit are largely found in northeast Kedah and Gunung Semanggol (Hutchison & Tan, 2009). The conglomerate is found along the eastern flank of Gunung Semanggol. Sediments at Gunung Semanggol are tightly folded and composed of lower rudaceous-arenaceous facies overlain by interbeds of sandstone and shale. Conglomerate generally forms the thickest beds and occurs interbedded with ill sorted sandstone at different horizon (Foo, 1990). The clasts size varies from gravel to pebble. The conglomerate of the Gunung Semanggol area is intraformational. The presence of intraformational conglomerate in the Semanggol formation proposes a period of contemporaneous erosion and deposition. The change in lithology from chert to sandstone and mudstone suggest that there was influx of nutrients and silica rich materials during the deposition of sediments (Jasin, Harun & Hassan, 2003).

2.4 AGE AND FOSSIL

Older studies stated that the age of the Semanggol Formation is of Triassic age (Burton, 1970; Courtier, 1974; Burton, 1988; Foo, 1990). However, discovery of Early Permian radiolarian has changed the age of the Semanggol Formation (Jasin, 2006). The discovery of these radiolarian faunas proposed that the base of chert unit in the Semanggol Formation is older than previously recorded. The latest studies documented show that the Semanggol Formation is recorded to be from Early Permian to Middle Triassic (Jasin, Harun, & Said, 2005a; Jasin, Harun, Said & Saad, 2005b; Jasin & Harun, 2007).

In peninsular Malaysia, radiolarians have been discovered mostly from chert and siliceous shale (The Malaysian-Thai Working Group, 2012). Thirteen species of radiolarian cherts were distinguished by Jasin (1994) located at Pokok Pauh, Bukit Tembaga, north Kedah and Merbau Pulas at south Kedah. The radiolarians indicate the age from Anisian to Ladinian, middle Triassic. However, no categorisation of assemblage zone was done. Subsequently, during his study in north and south Kedah, Jasin (1997) identified 32 species of radiolarian faunas from 20 chert samples. The radiolarian faunas are assigned to three different assemblage zones:

a) *Pseudoalbaillella scalprata* m. *rhombothoracata* – Early Permian
b) *Albaillella levis* – Late Permian
c) *Triassocampe deweveri* – Anisian to Ladinian, Middle Triassic

Jasin et al. (2005a) has updated their study at Kuala Ketil, south Kedah by placing *Triassocampe deweveri* assemblage zone into Late Anisian. Three assemblage zones of Triassic radiolarian have been marked which are:

a) *Entactinosphaera chikensis* – Late Olenekian, Early Triassic
b) *Triasscocampe coronata* – Middle Anisian, Middle Triassic
c) *Oertlispongus inaequispinosus* – Early Ladinian, Middle Triassic

Pseudoalbailella scalprata m. *rhombothoracata* assemblage zone discovered at Bukit Yoi, Pokok Sena is the oldest radiolarian zone in the Semanggol Formation, from late Sakmarian, late Early Permian (Jasin, 2008; Jasin & Harun, 2011).

In Kuala Ketil area, almost the whole sequences of chert that are exposed embody the whole range of radiolarians that represent the age of the Semanggol Formation (Harun et al., 2009). Discovery of Early Permian to Middle Triassic radiolarians suggests that the chert unit is not the oldest unit of the Semanggol Formation. The chert unit is partly interfingering with the rhythmite unit and conglomerate unit, deposited at more or less the same time (Jasin, 1997; Jasin & Harun, 2007). In another word, the three units were interpreted to be in lateral and intertonguing contact, having lateral facies variation rather than sequential superposition (Sashida et al., 1995; Harun & Jasin, 2007). Based on biostratigraphy studies done, radiolarian chert deposits are quite widespread especially in the Late Palaeozoic and Early Mesozoic of west Peninsular Malaysia. Therefore, radiolarian biostratigraphy is important to understand the deep marine sediments of Peninsular Malaysia (Jasin & Harun, 2011).

In addition, other fossils have also been found in the Semanggol Formation. Burton (1988) denoted bivalves faunas *Daonella* sp. found are of Ladinian age meanwhile *Posidonia* sp. and *Halobia* sp. are from Carnian. Foo (1990) has also discovered fossil fauna *Daonella* sp. and *Serpulites* sp. found in shale. He did not make further explanation on the age of the fossil fauna and only recognised them as Triassic fossils. In contrast, well-preserved foraminifera were discovered from siliceous mudstone at Bukit Lada and Merbau Pulas, south Kedah (Jasin, 2006). It is very rare that calcareous foraminifera in siliceous mudstone, and coexist with several species of radiolaria.

Table 2.2: Radiolarian biostratigraphy of Peninsular Malaysia from Early Permian to Late Triassic (Harun & Jasin, 2007)

Ma	Period	Epoch	Age	Assemblage zones
	TRIASSIC	Late	Rhaetian	
210			Norian	*Capnodoce*
			Carnian	
220		Middle	Ladinian	*Oertlispongus inaequispinosus*
230			Anisian	*Triassocampe deweri*
				Triassocampe coronata
240		Early	Olenekian	*Entactinosphaera chiakensis*
250			Induan	
	PERMIAN	Lupingian	Changhsiangian	*Neoalbaillella optima*
			Wuchiapingian	*Neoalbaillella ornithoformis*
260		Guadalupian	Capitanian	*Follicucullus porrectus*
			Wordian	*Follicucullus monacanthus*
			Roadian	*Pseudoalbaillella globosa*
270		Cisularian	Kungurian	*Pseudoalbaillella longtanensis*
280			Artinskian	
			Sakmarian	*Pseudoalbaillella scalprata* m. *rhombothoracata*
290			Asselian	*Pseudoalbaillella lomentaria*

2.5 DEPOSITIONAL SETTING

Burton (1988) marked that the depositional setting of Bedung area, Kedah is a flysch deep marine facies. Foo (1990) suggested that the presence of intraformational conglomerate in the Semanggol formation proposes a period of contemporaneous erosion and deposition. Jasin (1996) stated that the conglomerate facies was deposited on submarine fans, the interbedded sandstone and mudstone facies was deposited by weak turbidity current and lastly the chert facies were deposited in a deep basin.

The Malaysian and Thai Working Groups (2006) agreed on the depositional setting of outer (distal) submarine fan for the rhythmite unit and inner (proximal) submarine fan for the conglomerate unit. The turbiditic character of sandstone suggests that they were derived from area that was generating tremendous amount of sediments that were episodically transported into the basin.

Radiolarian oozes gather in modern deep sea, below area of high planktonic activity (Jasin & Harun, 2011). Therefore, it can be assumed that the radiolarian bearing cherts are deposited on ocean floor, away from terrigenous and carbonate sediment, in order for deposition of high silica ooze to occur (Hutchison & Tan, 2009). The fossil bearing siliceous sediments altered into radiolarian bearing rock were thought to be initially devoid of calcareous components, thus making them to be deposited under the Calcite Compensation Depth (CCD).

However, the Malaysian-Thai Working Group (2012) noted that the depositional settings for radiolarian cherts are not necessarily in deep marine oceanic basins with depth more than 3000 m. There are some indicators that the Mesozoic deposits may contain some calcareous component and the CCD was probably shallower in the modern deep ocean.

CHAPTER 3

METHODOLOGY

3.1 OVERVIEW

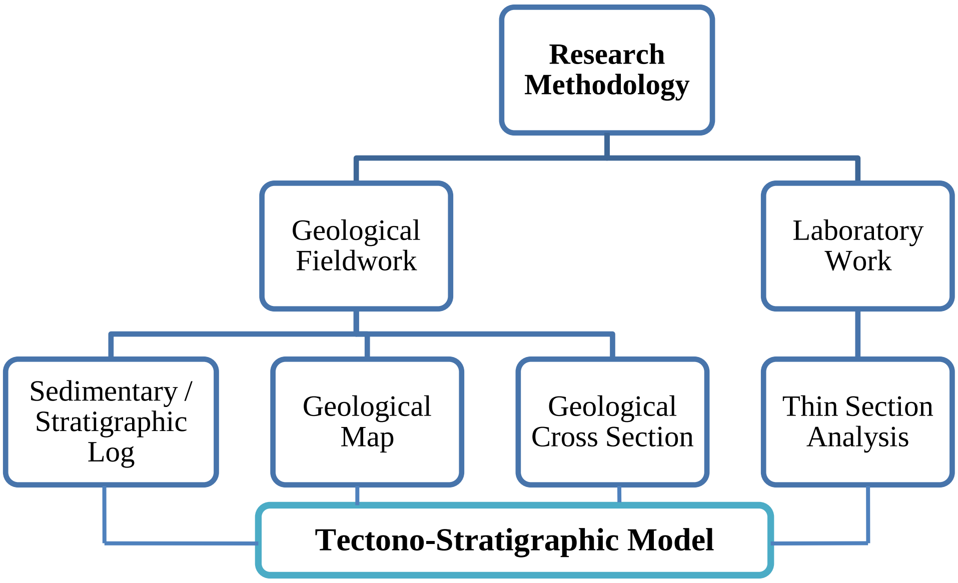


Figure 3.1: Proposed research methodology for Final Year Project I & II

3.2 PROJECT ACTIVITIES

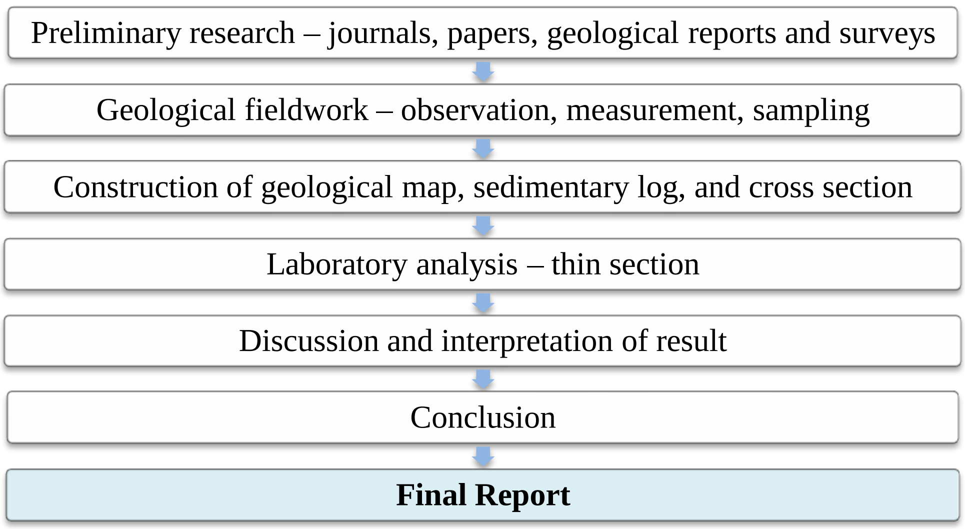


Figure 3.2: Project activities workflow for Final Year Project I & II

3.3 KEY PROJECT MILESTONES

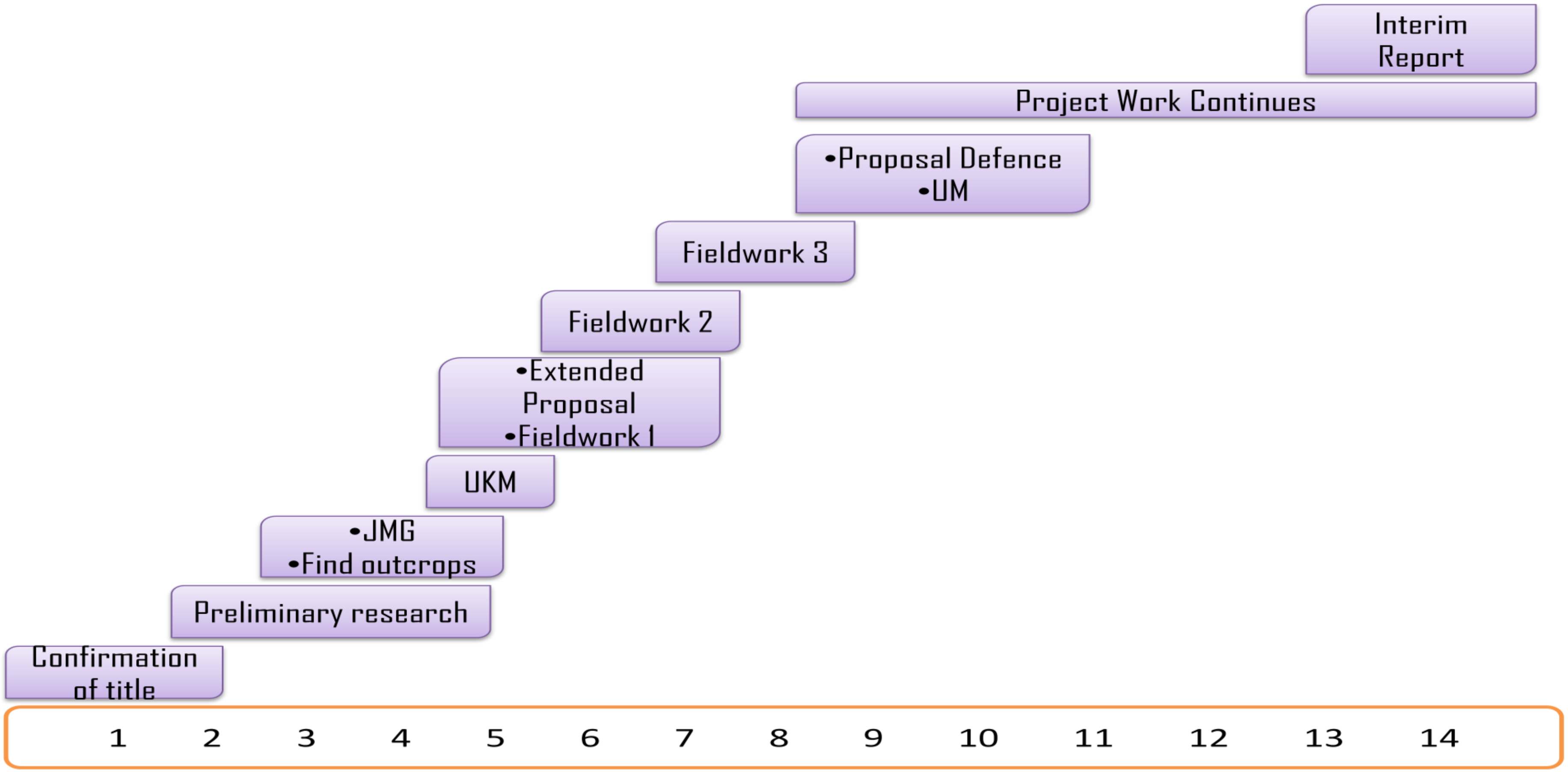


Figure 3.3: Key milestones of the project from Week 1 until Week 14

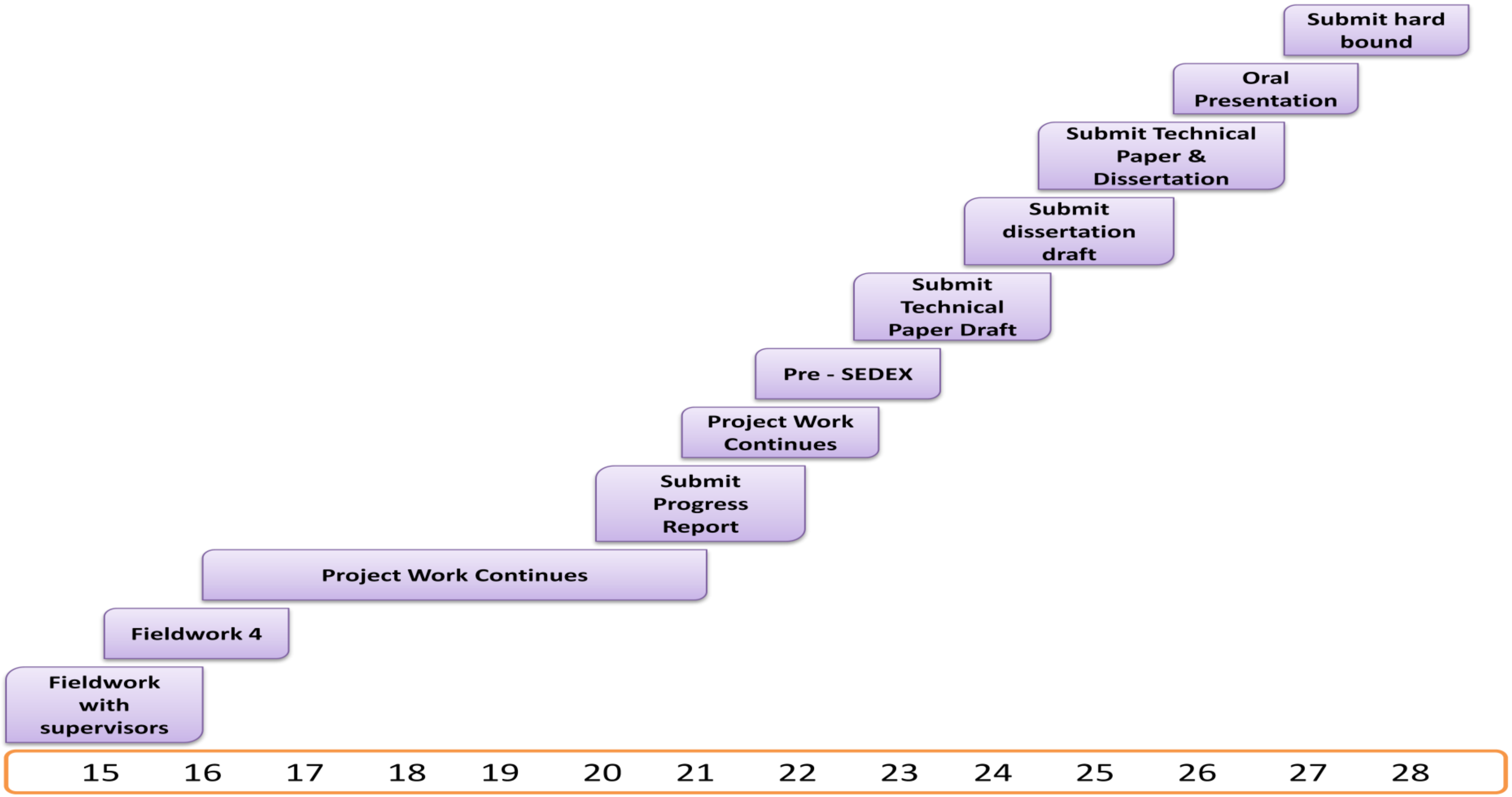


Figure 3.4: Key milestones of the project from Week 15 until Week 28

3.4 PROJECT TIMELINE

Table 3.1: Project schedule and development in Final Year Project I

Activity / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of Project Topic														
Preliminary Research Work														
Finding Potential Outcrops at Study Area														
Submission of Extended Proposal														
Fieldwork 1														
Fieldwork 2														
Fieldwork 3														
Proposal Defence														
Project Work Continues														
Submission of Interim Report														

Table 3.2: Project schedule and development in Final Year Project II

Activity / Week	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Fieldwork with Supervisors														
Fieldwork 4														
Project Work Continues														
Submission of Progress Report														
Project Work Continues														
Pre-SEDEX														
Submission of Technical Paper Draft														
Submission of Dissertation Draft														
Submission of Dissertation (Soft Copy)														
Submission of Technical Paper														
Oral Presentation - VIVA														
Submission of Dissertation (Hard Copy)														

3.5 GEOLOGICAL FIELDWORK

Preliminary research on the geology of northern Gunung Semanggol area involves geological fieldwork. Data collected during geological fieldwork will be used to build geological map, sedimentary / stratigraphic log and geological cross section.

The tools that are required during geological fieldwork are:

1. Brunton compass
2. Global Positioning System (GPS)
3. Hammer
4. Sample bags
5. Measuring tape
6. Field camera
7. Notebook
8. Measuring tape

3.5.1 SEDIMENTARY / STRATIGRAPHIC LOG

Stratigraphic column or log represents the succession of the rock layers in their manners of deposition in a vertical direction. This log shows the oldest and the youngest rocks units in a particular area. Construction of a sedimentary log requires observation and measurement of the rocks during geological fieldwork. The changes in rock type, the thickness of the rock units and their grain size are recorded. Additional information such as sedimentary structures, occurrence of fossils, bioturbations or faults can be put into the column.

Procedures in building a stratigraphic column are:

1. Divide the different rock units according to the lithology. Determine the scale of the log.
2. Measure the thickness of each unit.
3. Estimate the grain size of each unit.

4. Recognise characteristic sedimentary structures in each unit.
5. Describe provisional geological settings of the outcrop.

3.5.2 GEOLOGICAL MAP

The distribution of geological features of an area such as rock types, faults, strata and age can be shown with construction of a geological map. Geological maps are usually drawn on a base map that shows topography, roads or rivers. The information obtained during geological fieldwork is used in creating a geological map. Two important properties that are shown in a geological map are lithologies and orientations. Each colour in a geological map represents different rock units or lithologies with different age. The naming of the unit is optional, and a brief description of each rock unit is usually given at the bottom of the map.

The second property shows the orientation of planes and lines in the study area. Measurement of strike and dip of study area includes bedding, joints, faults and folds. Other than that, trend and plunge measurement shows that inclination of linear features. This information helps geologists to imagine the geological features in three dimensions. Most importantly, the contacts between lithologies can be determined.

The procedures in drawing a geological map are:

1. Identify formations and determine if any contacts between formations can be seen.
2. Record size, shape and distribution of rock units.
3. Plot the location of geologic contacts, faults, folds.

3.5.3 GEOLOGICAL CROSS SECTION

Geological cross sections are vertical slices through the earth demonstrating the surface and subsurface along a chosen line of section in geological map drawn earlier. In another word, geologic cross section views the earth as if it was cut open and viewed from the side. Strike and dip lines of section are commonly chosen in building a geological cross section.

Procedures in building a geological cross section are:

1. Select a section line.
2. Construct a topographic profile along the line of section.
3. Transfer contacts from geological map to the topographic profile.
4. Projects dip data into the cross section line.
5. Calculate and plot apparent dips on the topographic profile.
6. Construct the subsurface interpretation.

3.6 LABORATORY WORK

Laboratory works will be conducted during Final Year Project II to obtain detailed information of northern Gunung Semanggol. Laboratory works that are planned to be conducted include thin section analysis.

3.6.1 THIN SECTION ANALYSIS

Thin section analysis is microscopic examination of rock sample collected during geological fieldwork. Thin section analysis of rock samples uses concept of optical mineralogy. The optical properties of minerals and rocks are measured using petrographic microscope. Other than mineral constituents, properties such as texture, sorting and porosity can be identified. The origin of the rocks can be established by studying their mineralogical composition.

The procedures in the preparation of thin section include:

1. Examine rock sample. Determine whether the rock sample needs epoxy stabilisation.
2. Section the rock sample into small cuttings that will fit onto the glass slide. Grind the sample to a flat surface.
3. Insert the sample in a sample hardening cylinder. Pour the prepared epoxy into the cylinder until the sample is full submerged in the epoxy.
4. Place the cylinder in a vacuum oven. Let the sample dry for 2-3 days.

5. After the sample has dried, bond the prepared sample to a glass slide for re sectioning. Ensure that the sample flat surface is attached to the glass slide.
6. Using precision cutter, the rock sample is cut until it is a few mm thin.
7. Final polishing and grinding is done to produce a rock sample thin section with thickness of approximately 30 µm.
8. Check the sample under a microscope to ensure that the sample minerals are visible.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 STUDY AREA DESCRIPTION

Figure 4.1: Aerial photograph shows outcrops observed during geological fieldwork

A total of 6 outcrops have been observed during geological fieldwork. Four outcrops are located on the east face of the northern Gunung Semanggol, one on the west face, and one at Bukit Merah. Rock samples are collected from each outcrop for further testing in the laboratory.

4.1.1 OUTCROP 1

Figure 4.2: Outcrop 1 used as reference for sedimentary logging

Figure 4.3: Bedded chert interbedded with shale

Figure 4.4: Evidence of shortening and compression

Outcrop 1 is located on the east face with coordinate N 04^0 58’ 17.86’’, E 100^0 39’ 54.51’’. The outcrop has total thickness of approximately 50 meters and width of 200 meters. The rock type of the area is predominantly bedded chert, with intercalation of silt and shale between the bedded chert. Evidence of deformation are spotted with some part of the outcrop has undergone shortening and compression from East-West direction, as seen from sigmoid shaped deformation and folding. The bedded chert has constant thickness from bottom to the top of approximately 10 cm, and the silt and shale lamination varies in thickness from a few mm to 2 cm.

4.1.2 OUTCROP 2

Figure 4.5: Highly weathered chert with eroded shale

Figure 4.6: Shale lamination between thinly bedded chert

This outcrop is located on the east face with GPS coordinate N 04^0 58' 8.04'', E 100^0 39' 58.87''. The lithology of this area is similar to Outcrop 1, thinly bedded chert with similar thickness. This height of this outcrop is about 25 meters and the width is approximately 150 meters. Thin lamination of shale can be seen between the bedded chert, in Figure 11. No structural evidence such as fold, fault seen at this area. The chert is reddish brown in colour meanwhile the shale in pale to dark grey. The rock has undergone a great deal of weathering. The shale is brittle and can be broken easily. Meanwhile, the chert is hard and resistant to erosion. One rock sample is taken from this outcrop for laboratory works.

4.1.3 OUTCROP 3

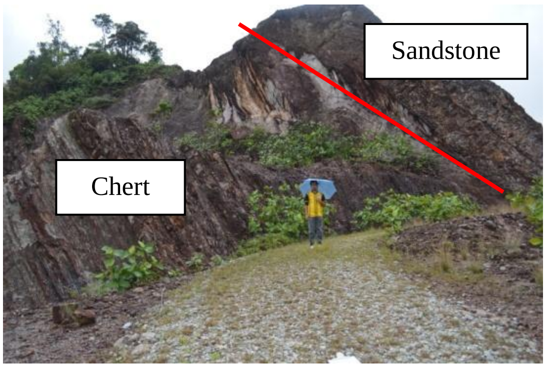


Figure 4.7: Angular bedding chert and massive sandstone body

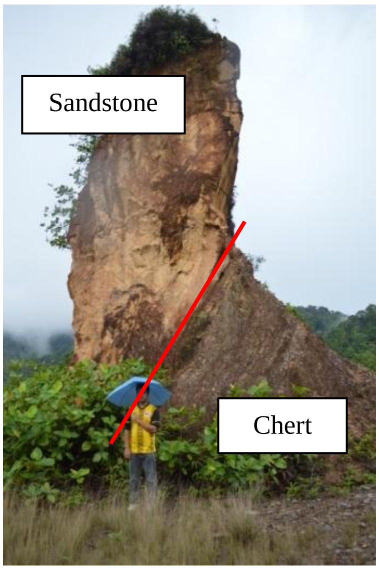


Figure 4.8: Contact between sandstone at the top and bedded chert at bottom

The GPS coordinate of Outcrop 3 is N 04^0 57' 53.6'', E 100^0 39' 37.92'' on the east face of northern Gunung Semanggol. This outcrop is important because the contact between the chert and sandstone can be examined clearly. The sandstone beds overly the chert beds. It can be said that the chert beds are older than the sandstone beds, and conform to theories published on the Semanggol Formation. The chert bed has similar thickness on each bed, with intercalation of shale between the chert beds. No visible bedding observed on the sandstone, it exists as one massive sandstone body.

4.1.4 OUTCROP 4

Figure 4.9: Visible fining upward sequence from left to right

Figure 4.10: Sandstone interbedded with thin shale lamination on the upper sequence

Outcrop 4 is located at N 05^0 0’ 0.92’’, E 100^0 39’ 18.16’’. This outcrop is located at Bukit Merah, approximately 1 km north of the northern Gunung Semanggol. This outcrop is similar to Outcrop 3, in which the boundary between bedded chert and sandstone interbedded with shale can be observed. Fining upward sequence can be seen clearly with massive sandstone at the bottom and silt and shale dominate at the upper part. Each sandstone bed has thickness from 70 to 100 cm meanwhile silt and shale range from a few cm to 10 cm. Structures such as fold and fault is not observed. Way up structures such as load cast is observed at the bottom of sandstone beds that show the attitude in which the sediments were originally deposited.

4.1.5 OUTCROP 5

Figure 4.11: Outcrop 5 observed during geological fieldwork

Figure 4.12: Chert interbedded with siltstone and shale, also known as ribbon bedded chert

Outcrop 5 is located at geographical coordinates N 04^0 58’ 12.8’’, E 100^0 39’ 42.7’’. This outcrop is located on the east face of the northern Gunung Semanggol. The outcrop has flat bedding orientation. Structural features such as fault and folding is not observed at the outcrop. The total thickness of the outcrop is approximately 14 meters. Some parts of the outcrop are covered with small trees and bushes. Two rock samples are collected from this outcrop. The dominant lithology of the outcrop is alternation of chert beds with shale beds. Some siltstone exists, intercalated with shale bed. Siltstone and shale that are interbedded with the chert are in bigger amount compared to the other outcrops. The shale is dark to pale gray in colour, exhibit thin laminations. In some part of the outcrop, the shale is eroded.

4.1.6 OUTCROP 6

Figure 4.13: Highly weathered and eroded sandstone ridges at Outcrop 6

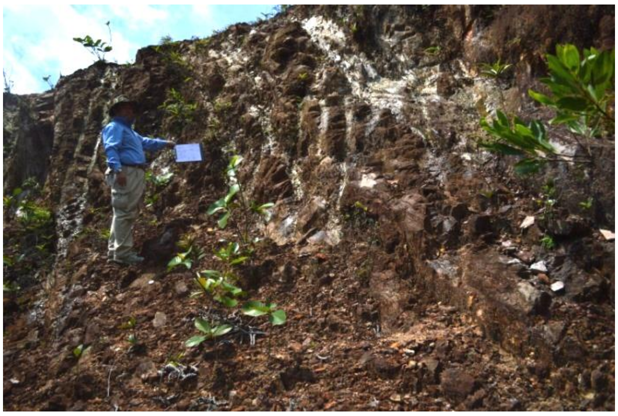


Figure 4.14: Nearly vertical sandstone beds

Outcrop 6 is located at N 04^0 57' 59.49'', E 100^0 39' 13.44'' on the east face of northern Gunung Semanggol**.** The outcrop is dominantly sandstone ridges, with less chert beds. The bedding of the sandstone is not clearly visible. The thickness of the outcrop is about 15 meters and the width approximately 50 meters. Shale lamination is observed between the sandstone beds, but with lesser amount compared to the other outcrops. Each sandstone bed has thickness ranging from 5 to 10 cm meanwhile the shale has thickness from a few mm to 2 cm. One rock sample is gathered from this area.

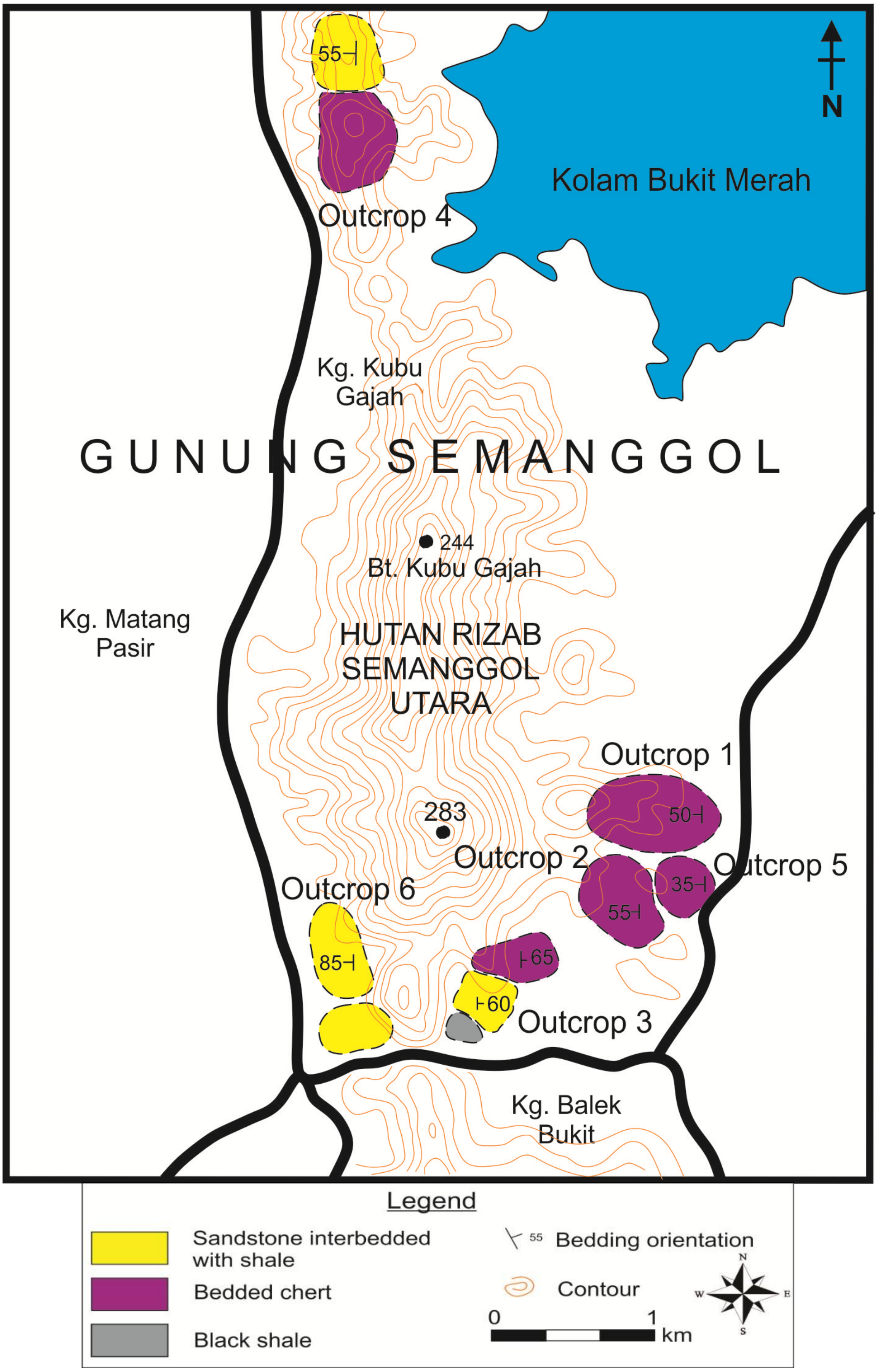


Figure 4.15: Lithology of each outcrops based on observation during geological fieldworks.

4.2 SEDIMENTARY / STRATIGRAPHIC LOG

Sedimentary logs show the manner in which the rocks were deposited from the oldest to the youngest. Six sedimentary and stratigraphic logs have been constructed based on observation and examination of outcrops during geological fieldwork, attached in the Appendix section of this report. Outcrop 1 and 2 show rhythmically bedded chert and shale laminations. The bedded chert and shale lamination exhibit similar thickness from bottom to top of the rock formations. The grain size of the chert is observed to be from fine sand to medium sand particle size. Meanwhile the shale laminations have mudstone or clay particle size. Each bedded chert is measured to have thickness from 6 cm to 8 cm meanwhile the shale lamination is a few mm to 2 cm with thinner sand beds approximately 1 cm to 2 cm between them. The ratio between sand and mud is 60% and 40% respectively.

Progression towards south of northern Gunung Semanggol discovered contact between rhythmically bedded chert at the bottom and massive sandstone body at the top. From the sedimentary section logged at Outcrop 3, it can be seen that the bedded chert has similar thickness from bottom to the top from 6 cm to 9 cm. This bedded chert may be in correlation to the bedded chert at Outcrop 1 and 2. The thickness of the sandstone body is measured to be approximately 2 meters. It occurs as one massive body with no visible beddings. The unconformity between the chert and sandstone body may imply the transition from Permian chert into Triassic siliciclastic materials. However, further research need to be done and it is safe to describe the rock formation as Permo-Triassic Semanggol Formation, as suggested by previous workers.

Outcrop 4 shows bedded chert, followed by a clear fining upward sequence of sandstone at the bottom followed by siltstone and shale to the top. The boundary between the bedded cherts and siliciclastic materials can be seen. Sedimentary log of Outcrop 4 shows that each sandstone bed possesses thickness from 70 cm to 1 meter. The sandstone exhibits very fine to medium size particles. Going up the sedimentary log, silt and clay size particles start to dominate. Each siltstone bed has thickness of 1 cm to 2 cm meanwhile the shale lamination is a few mm to 2 cm thick.

Outcrop 5 is located at the east face of the northern Gunung Semanggol. The sandstone is abundant compared to the chert. The sedimentary logging was done on rock formation that is 20 meters in height and 20 meters wide. The thickest chert bed is 100 cm thick and decreases upwards with the thinnest are approximately 20 cm thin. The shale is interbedded between the chert beds and is from a few mm to 5 cm thickness. In some part of the outcrop, the shale beds are eroded; making the chert beds looked protruded.

Outcrop 6 is made of sandstone and shale body 20 meters in thickness and 50 meters wide. It is observed that a few sandstone ridges exist on the west face of northern Gunung Semanggol. Outcrop 6 is chosen to represent these sandstone ridges as it is accessible and exposed. The sandstone beddings at this outcrop are nearly vertical. Each sandstone bed ranges 70 cm to 120 cm thick. Intercalation of silt and clay sized particles dominate the upper part of the sedimentary log. Laminated shale has a few mm to 2 cm thickness, and intercalated with silt sized particles.

4.2.1 DEPOSITIONAL SETTINGS

Depositional environment of Gunung Semanggol is typically deep marine environment. Overall, the lithology of the northern Gunung Semanggol is chert sequence at the bottom, followed by interbedded sandstone and shale in the upper part, representing a shallow upward sequence. The transition of depositional settings can be seen clearly at Outcrop 4, consisted of deep marine bedded chert and interbedded turbiditic sandstone and shale.

It is suggested that Outcrop 1 and 2 was formerly deposited in deep marine setting during Permian time. The evolution of the Permian bedded chert in deep marine setting will be explained in the next section. These Permian bedded cherts were deposited in deep marine settings below Calcite Compensation Depth (CCD). No calcareous materials are found at Semanggol Formation, proving that chert deposition would only occur below CCD. However, this depth might be shallower in areas of high plankton productivity.

On the other hand, turbidite sediments are associated with deep marine sedimentation of submarine fans. Based on the sequence of interbedded sandstone and shale of Outcrop 4, 5 and 6 the sediments may be deposited from middle fan to outer fan. The ratio of sand compared to shale is still abundant, but they exist as thin beds, showing progression towards distal submarine fan. The turbidite sequences overlie the bedded chert in Semanggol Formation, in deep marine settings with occasional sand influx.

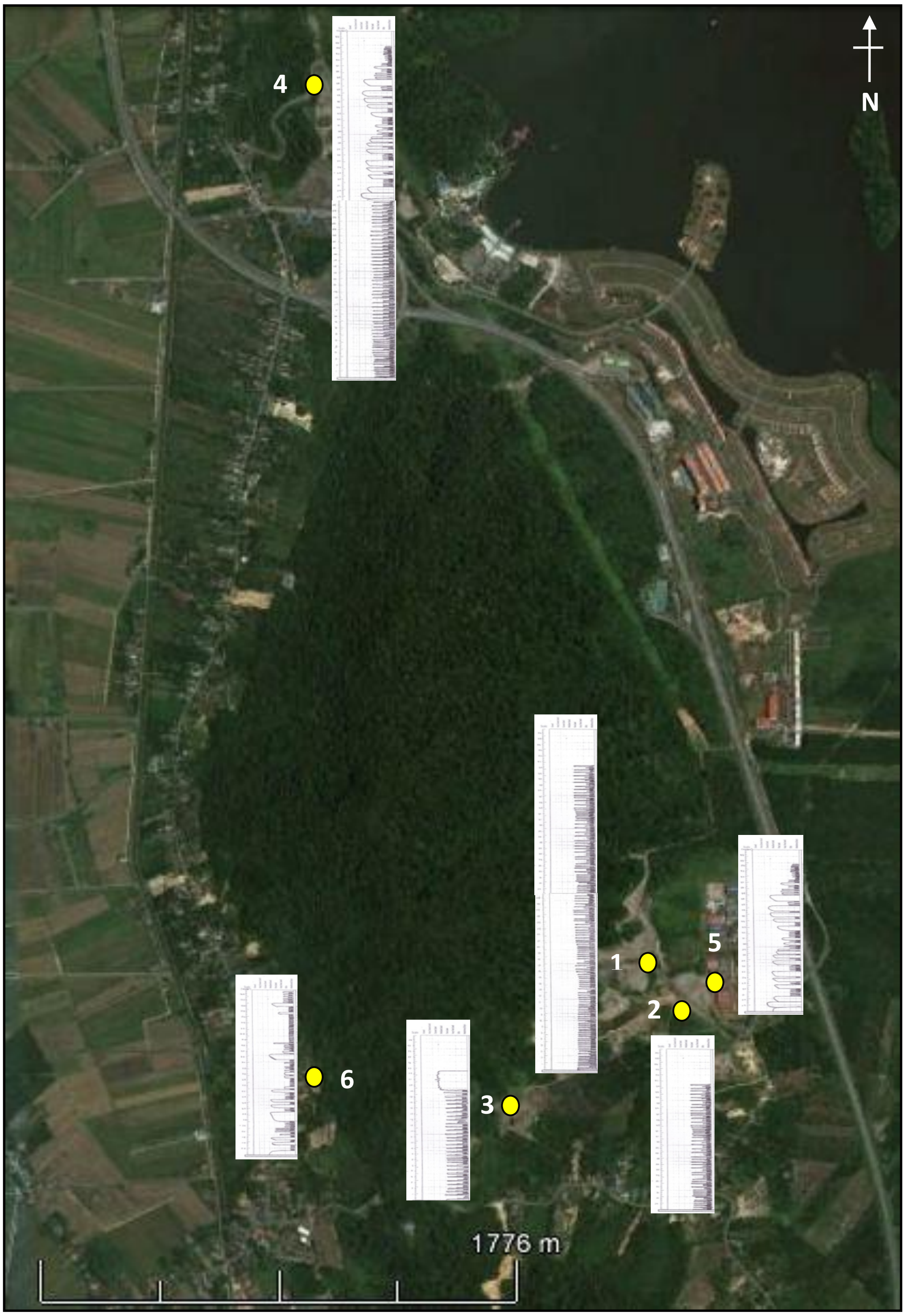


Figure 4.16: Sedimentary logs constructed on each outcrop

4.3 STRUCTURAL ANALYSIS

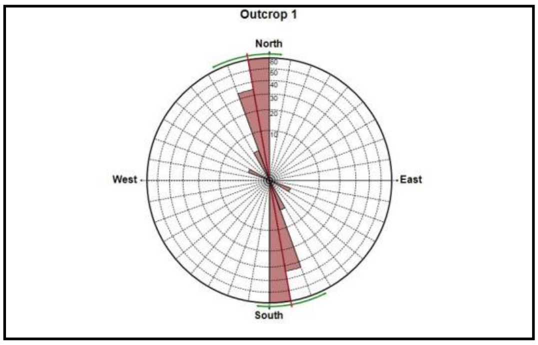


Figure 4.17: Strike reading taken from Outcrop 1

Table 4.1: Properties of reading of Outcrop 1

GPS Coordinate	N 04^0 58’ 17.86’’ E 100^0 39’ 54.51’’
Mode	Bidirectional
Number of measurements	50
Mean	9.98^0
Standard deviation	$\pm16.70^0$

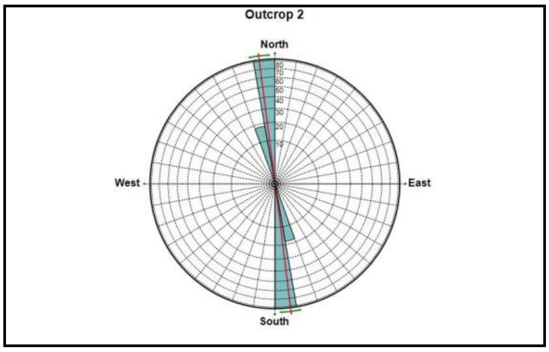


Figure 4.18: Strike reading taken from Outcrop 2

Table 4.2: Properties of reading of Outcrop 2

GPS Coordinate	N 04^0 58’ 8.04’’ E 100^0 39’ 58.87’’
Mode	Bidirectional
Number of measurements	50
Mean	7.13^0
Standard deviation	$\pm5.18^0$

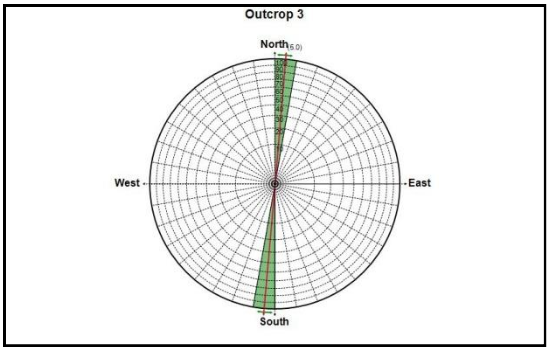


Figure 4.19: Strike reading taken from Outcrop 3

Table 4.3: Properties of reading of Outcrop 3

GPS Coordinate	N 04^{0} 57' 53.6'' E 100^{0} 39' 37.92''
Mode	Bidirectional
Number of measurements	50
Mean	5.00^{0}
Standard deviation	±3.69^{0}

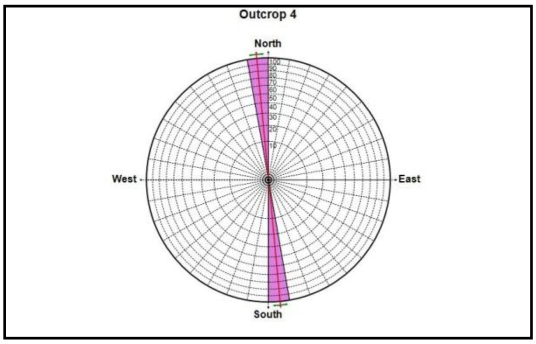


Figure 4.20: Strike reading taken from Outcrop 4

Table 4.4: Properties of reading of Outcrop 4

GPS Coordinate	N 05^{0} 0' 0.92'' E 100^{0} 39' 18.16''
Mode	Bidirectional
Number of measurements	50
Mean	5.44^{0}
Standard deviation	±3.60^{0}

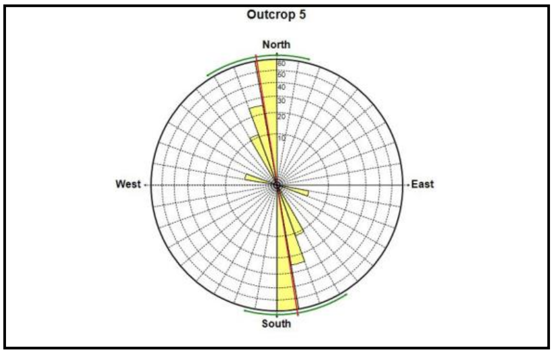


Figure 4.21: Strike reading taken from Outcrop 5

Table 4.5: Properties of reading of Outcrop 5

GPS Coordinate	N 04^0 58' 12.8'' E 100^0 39' 42.7''
Number of measurements	80
Mean	9.20^0
Standard deviation	±24.02^0

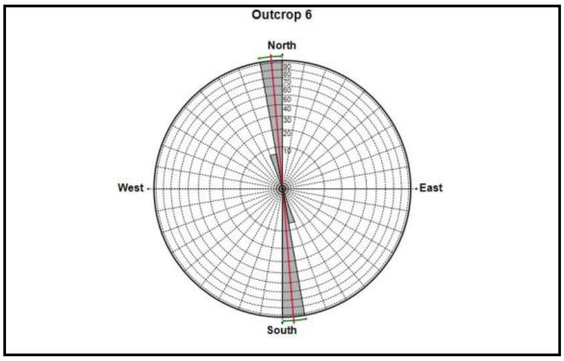


Figure 4.22: Strike reading taken from Outcrop 6

Table 4.6: Properties of reading of Outcrop 5

GPS Coordinate	N 04^0 57' 59.49'' E 100^0 39' 13.44''
Mode	Bidirectional
Number of measurements	50
Mean	5.00^0
Standard deviation	±3.69^0

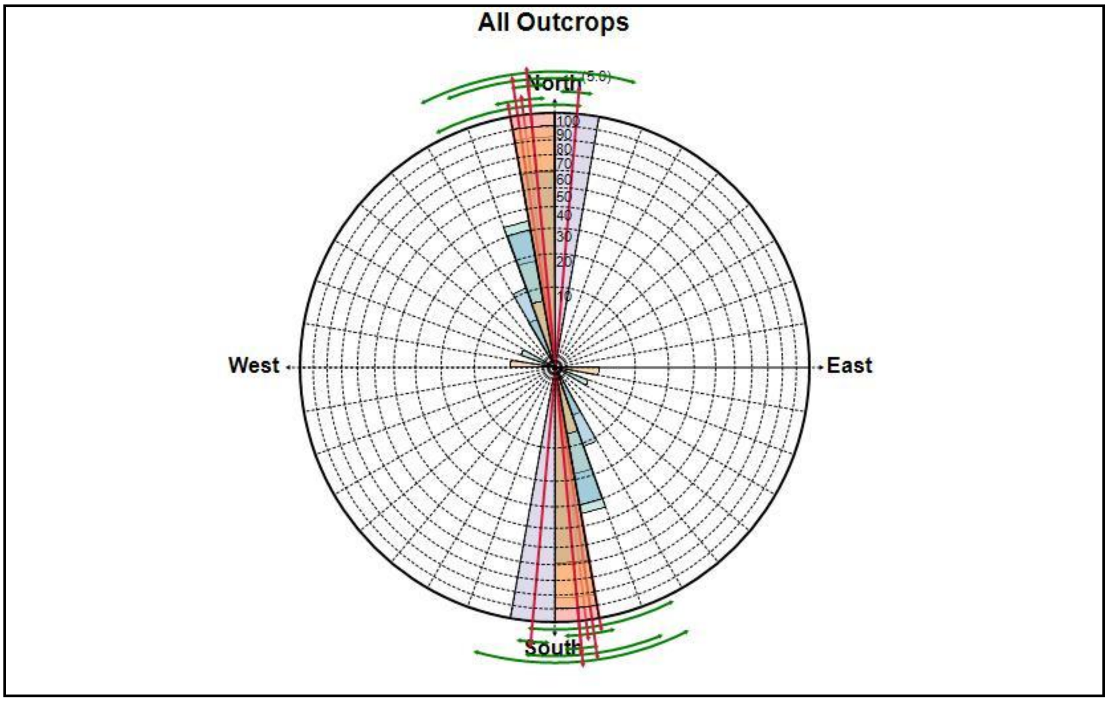


Figure 4.23: Combination of rose diagrams from Outcrop 1 to Outcrop 6

Comprehensive geological study of an area includes measurement and data recording. Strike and dip reading were taken at the six outcrops of northern Gunung Semanggol. The strike of northern Gunung Semanggol is generally in N-S trending direction. Average strike reading is from 165^0 - 180^0 meanwhile the dip varies from 40^0 until $65^{0.}$ It is observed that the dip is getting higher from east to west. Outcrop 6 has nearly vertical bedding with dip reading from 80^0 to $90^{0.}$All of the outcrops dip towards the west except for Outcrop 3, to the east. It is postulated that a syncline may have formed resulting in the different dip direction.

From the rose diagrams, the force of compression came from East – West direction, which can be related to the collision of Sibumasu continental block and East Malaya-Indochina block. This deformation causes the N-S trending of the Semanggol Formation. The forces of compression are stronger on the west and diminish to the east. This could be related to westward thrusting of Sibumasu terrane that collided with Indochina- East Malaya terrane, causing the closure of Palaeo-Tethys Ocean. The westward thrusting would provide abundant chert that may have been originated from the bed of Palaeo-Tethys Ocean and siliciclastic materials that produced turbidite sequence.

4.3.1 SECONDARY STRUCTURES

Secondary structures are those develop in rocks after their formation as a result of their subjection to external forces. Secondary structures include faults, folds, joints and shear fractures, shear zones, cleavage, foliation, and lineation. The deformation of rocks resulted in change of shape from some initial condition to deformed configuration.

Figure 4.24: Sub-conjugate joints at Outcrop 5

Figure 4.24 shows joint sets that are found at Outcrop 5. Joints commonly represent mode I fracture development. Mode I explains tensile cracks, in which the fractures open in perpendicular direction to crack surface. The joint sets at this outcrop are classified as systematic joints, having group of parallel to sub-parallel. Plus, the joints are evenly spaced to one another. The dihedral angle of the joint system is sub-conjugate, with dihedral angle between 30^o - 60^0.

Figure 4.25: S-shaped shear deformation at Outcrop 1

Figure 4.25 shows sinistral (left-handed) shear that commonly occur in ductile shear zone. S-shaped gashes at Outcrop 1 are caused by shear compression, where the shorter limbs appear to have been rotated counter clockwise. The upper limbs seem to have displaced to the left, and the lower limb displaced to the right.

Figure 4.26: Large, low angle truncation at the bottom right

Figure 4.26 shows a large, low angle truncation seen at Outcrop 1. The layers of sediments below are truncated, cut off and deposition of new sediments occurred.

4.3.2 SEDIMENTARY WAY-UP STRUCTURES

Figure 4.27: Load cast features determine the stratigraphic way up

Recognition of sedimentary way-up structure is important before proceeding with geological work, as it determine the attitude in which the layers of sediments were deposited. Examples of way-up structures include graded bedding, load cast, flame structures, groove marks and tools. Stratigraphic and sedimentary logging can only be done after determining way-up of the formation. Figure 4.27 shows load cast that formed on the base of sandstone at Outcrop 4. Load cast occur when a higher density material such as sand deposited on lower density sediments like clay and mud.

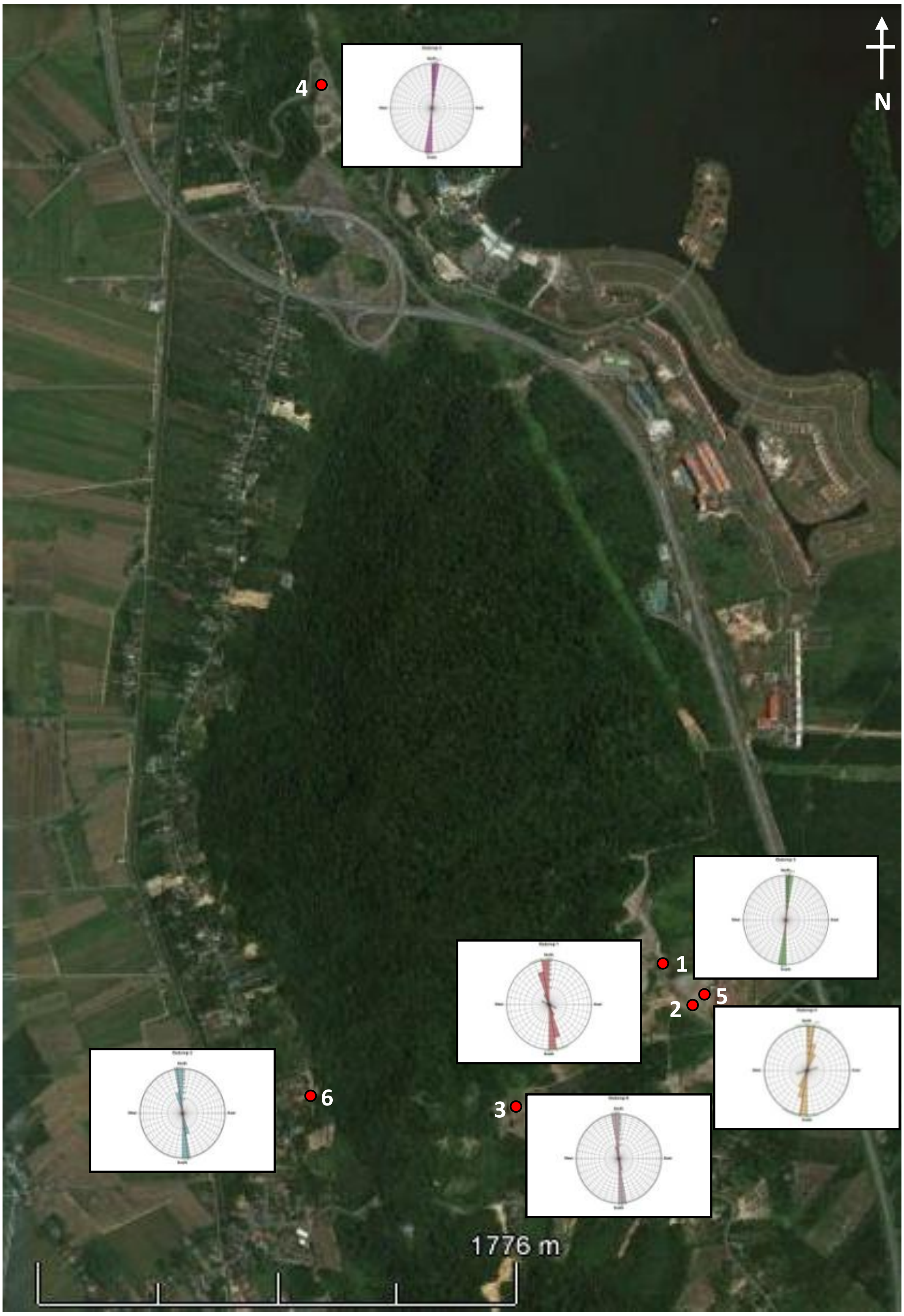


Figure 4.28: Bedding orientation of each outcrop at northern Gunung Semanggol

4.4 GEOLOGICAL MAP AND GEOLOGICAL CROSS SECTION

Figure 4.29: Geological map of northern Gunung Semanggol

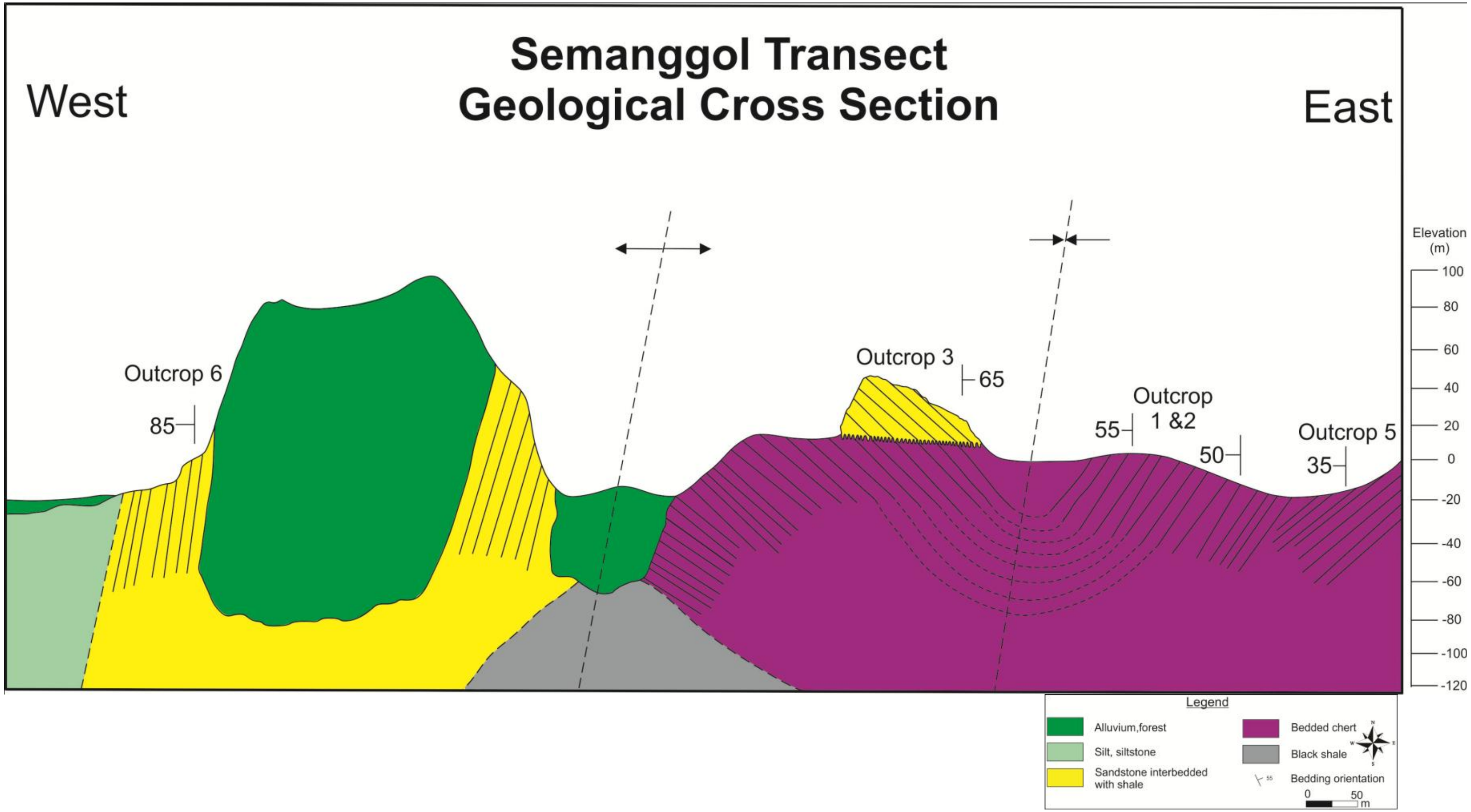


Figure 4.30: Semanggol transect geological cross section from line A to A’

4.5 LITHOSTRATIGRAPGY

4.5.1 LITHOFACIES ASSOCIATION

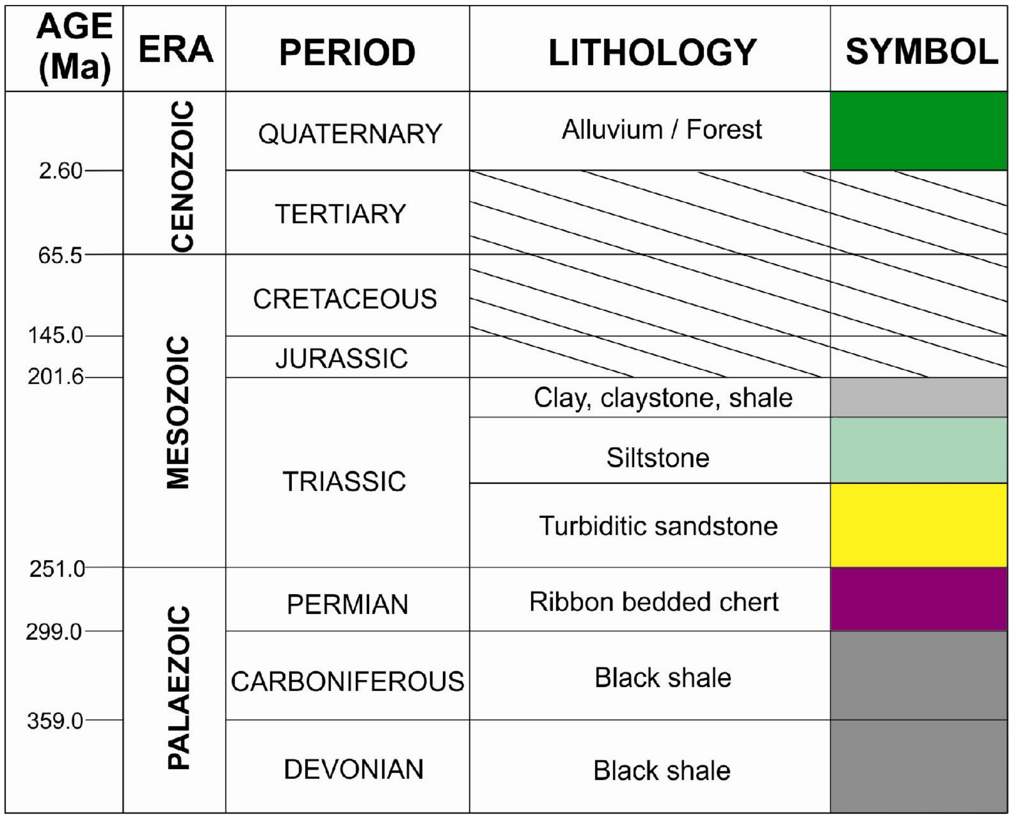


Figure 4.31: Stratigraphic chart of northern Gunung Semanggol

<u>Sandstone Interbedded with Shale Lithofacies</u>

The deposition of sandstone interbedded with shale is said to be related to submarine fans and turbidites deep marine sedimentation. Turbiditic sandstone at Outcrop 4 is deposited at the continental rise of a passive margin, where the turbidity currents start to slow and settle down. Turbidity current is influenced by density current that flow down slope along the ocean bottom. The sediments are suspended in turbidity current under the action of gravity. At some point, the flow will stop when there is no density contrast between the sediments and surrounding water. Bouma sequence represents five ideal structural units that explain the characteristics of turbidites. These structural divisions show development of different sedimentary structures according to the strength of turbidity current.

From the sedimentary log constructed of northern Gunung Semanggol, it can be suggested that only Bouma interval Tb and Td exist. Bouma interval Tb is distinguished by parallel laminae of sand. It comprises of medium sand, grading vertically into fine and very fine sand. The Tb interval is recognised at Outcrop 4, 5 and 6 where the sandstone beds have plane parallel sand beds. The grain sizes at these outcrops range from very fine to fine, with sharp base. On the other hand, Td is represented by parallel lamination that is made up of clay and silt. Thick shale lamination can be seen at the upper part of Outcrop 4, with smaller laminae in between them.

The interbedded sandstone and silt, clay shows middle to outer fan settings, of deep marine fan deposits. Observation from field work decided that the turbidite model of the northern Gunung Semanggol is said to be sand-rich submarine fan system, due to high ratio of sand size particles compared to silt and clay size particles in all of the outcrops.

Ribbon bedded chert Lithofacies

The cherts in Peninsular Malaysia are associated with clastic rocks, specifically shale. The cherts of Semanggol Formation exist as bedded chert, consists of layers of chert ranging from several centimetres in thickness that are interbedded with laminae of shale. Chert is composed of dominantly SiO_2 minerals such as quartz, chalcedony, and opal. These bedded cherts originated from remains of siliceous organisms such as radiolarians and micro planktons. These organisms build skeletons of opaline silica are abundant enough in the ocean to produce chert. Once the micro planktons died, their siliceous skeletons settled at the ocean bottom as silica oozes. These silica oozes were compacted and undergone induration and become radiolarian chert. Cherts are hard and very resistant to weathering, making them form the ridges of northern Gunung Semanggol.

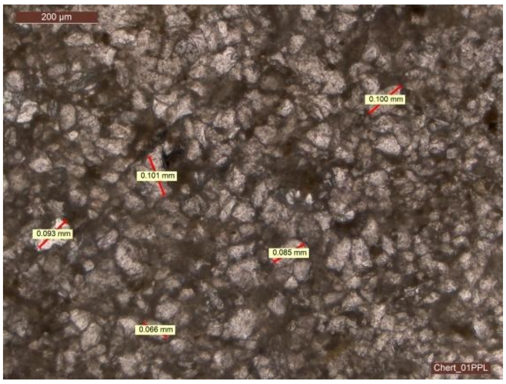
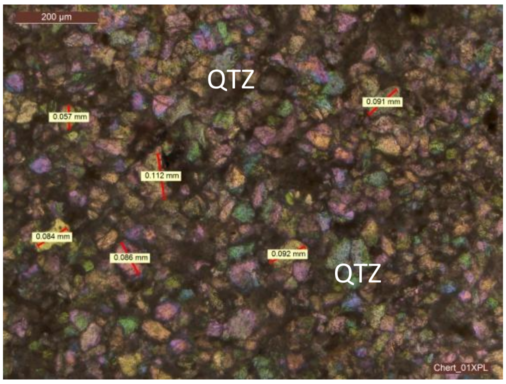
Chert / shale rock association is very widespread and represent deep marine environment along continental margin. The vertical change of lithology from chert / shale association to turbiditic sandstone and shale suggest that the depositional environment was close to continental margin from which occasional influx of sand was derived by turbidity currents.

Black Shale Lithofacies

Black shale deposits are found only at Outcrop 3. The black shale was lithified and indurated. The black shale at Outcrop 3 has clay grain size particles. Black shales are deposited in reducing, anoxic environment where the water is deep. They formed in basins where there is lack of currents and oxygen levels remain the same. Black shales contained organic carbon originated from remains of dead organisms that settled on the ocean bottom. These rocks may have been formed during the Carboniferous time, where the sea level was high, as it was the time of opening and growth of the Palaeo-Tethys Ocean. Black shales are not found at other outcrops, as they may be unexposed and buried.

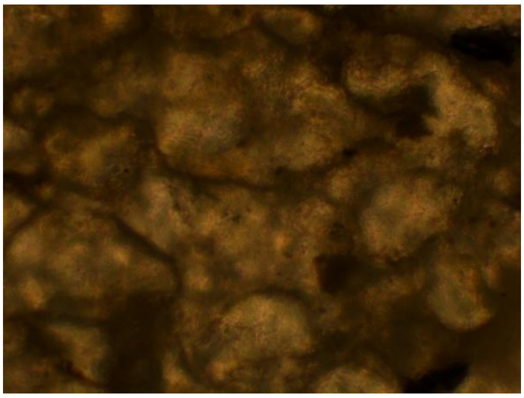
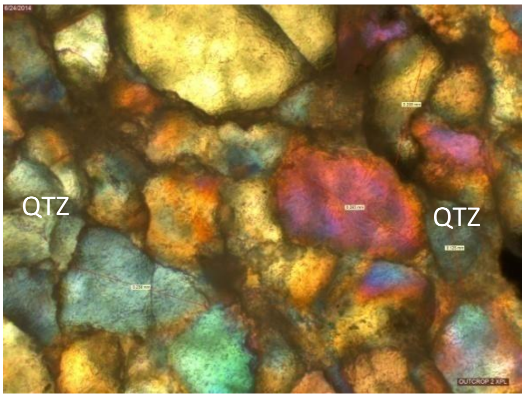
4.6 THIN SECTION ANALYSIS

4.6.1 OUTCROP 1

	
Plain polarised light (PPL)	Cross polarised light (XPL)

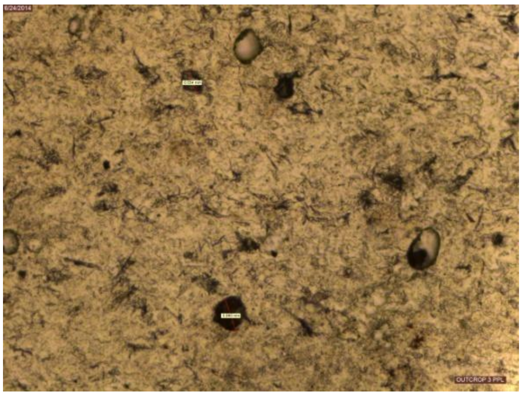
Features	Comment
Rock type	Chert
Grain size	0.0625 mm – 0.125 mm Very fine sand – fine sand *Based on Udden-Wenworth grain-size classification scheme (Wenworth,1992)*
Texture	Low sphericity Angular grains Moderately sorted No preferred grain orientation
Porosity	Intergranular porosity Porosity reduced by infilling of clay minerals between grains
Compaction	No evidence of compaction Grain to grain contact

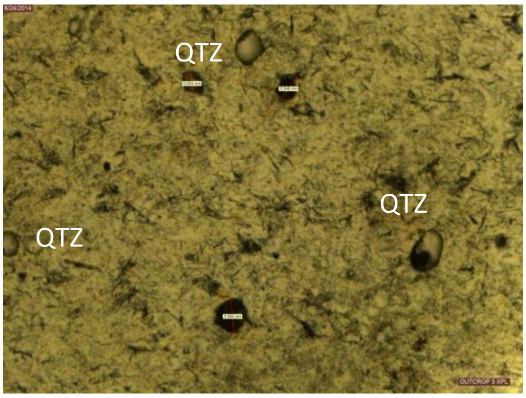
4.6.2 OUTCROP 2

	
Plain polarised light (PPL)	Cross polarised light (XPL)

Features	Comment
Rock type	Chert
Grain size	0.125 mm – 0.30 mm Fine sand – medium sand *Based on Udden-Wenworth grain-size classification scheme (Wenworth,1992)*
Texture	Low sphericity Angular grains Moderately sorted No preferred grain orientation
Porosity	Intergranular porosity Porosity reduced by infilling of clay minerals between grains
Compaction	No evidence of compaction High grain to grain contact

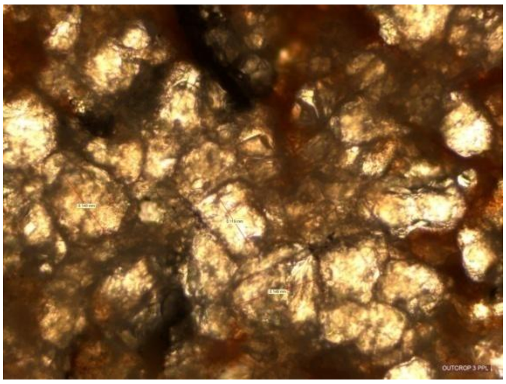
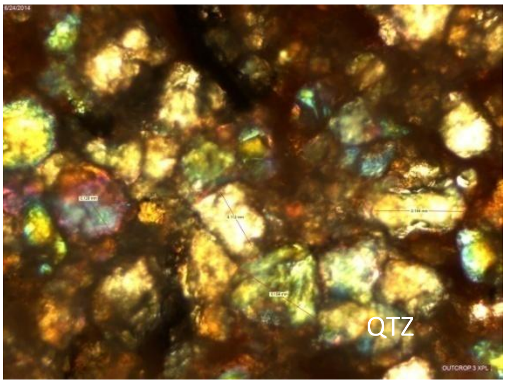
4.6.3 OUTCROP 3



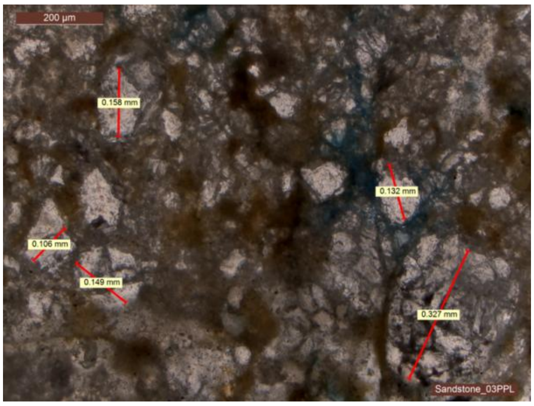


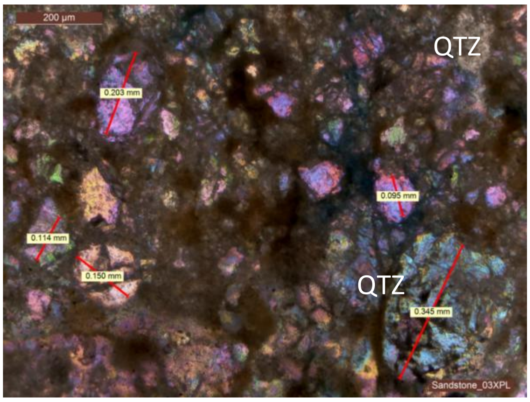
Plain polarised light (PPL)	Cross polarised light (XPL)

Features	Comment
Rock type	Black shale
Grain size	0.0625 mm – 0.125 mm Very fine sand – fine sand *Based on Udden-Wenworth grain-size classification scheme (Wenworth,1992)*
Texture	Low sphericity Angular grains Moderately sorted No preferred grain orientation
Porosity	No or low porosity Black shale has been lithified/ compacted
Compaction	Compaction/ lithification Grain to grain contact

	
Plain polarised light (PPL)	Cross polarised light (XPL)

Features	**Comment**
Rock type	Chert
Grain size	0.0625 mm – 0.125 mm Very fine sand – fine sand *Based on Udden-Wenworth grain-size classification scheme (Wenworth,1992)*
Texture	Low sphericity Angular grains Moderately sorted No preferred grain orientation
Porosity	Intergranular porosity Porosity reduced by infilling of clay minerals between grains
Compaction	No evidence of compaction High grain to grain contact

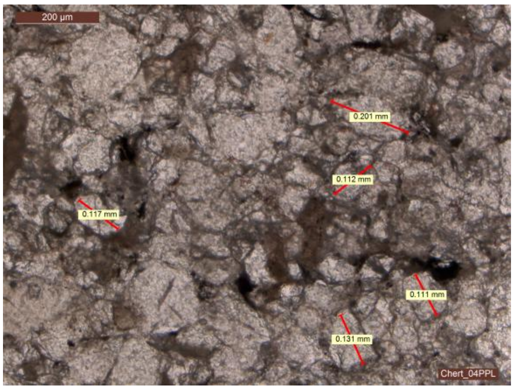




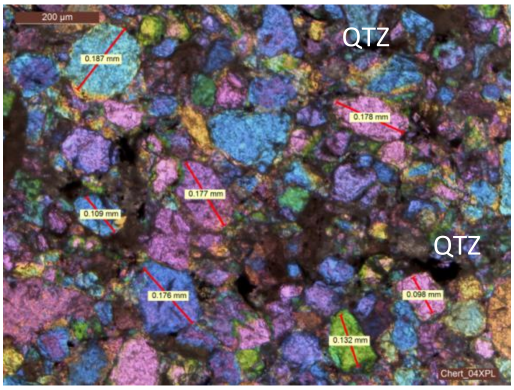
Plain polarised light (PPL)	Cross polarised light (XPL)

Features	Comment
Rock type	Sandstone
Grain size	0.0625 mm – 0.50 mm Very fine sand – Medium sand *Based on Udden-Wenworth grain-size classification scheme (Wenworth,1992)*
Texture	Low sphericity Angular grains Moderately sorted No preferred grain orientation
Porosity	Intergranular porosity Porosity reduced by infilling of clay minerals between grains
Compaction	No evidence of compaction High grain to grain contact

4.6.4 OUTCROP 4



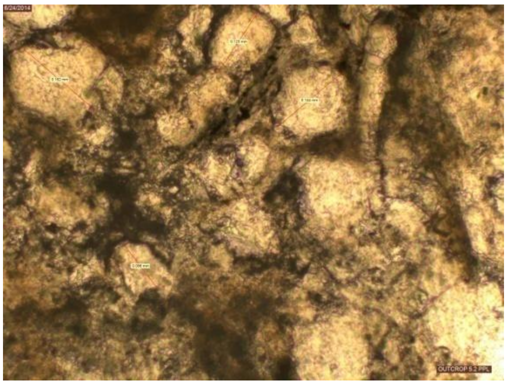
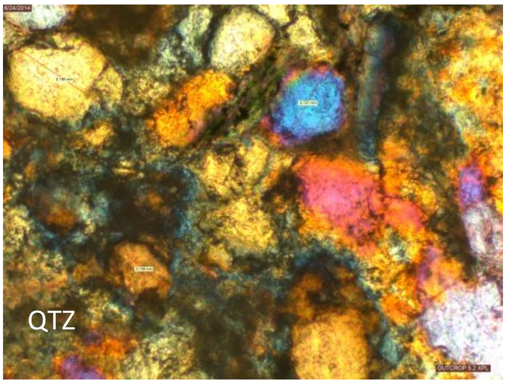
Plain polarised light (PPL)



Cross polarised light (XPL)

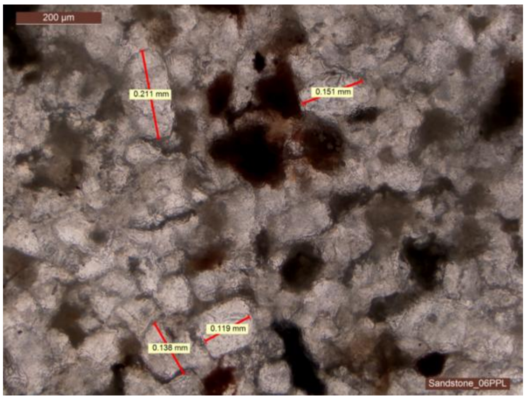
Features	**Comment**
Rock type	Chert
Grain size	0.25 mm – 0.50 mm Medium sand – coarse sand *Based on Udden-Wenworth grain-size classification scheme (Wenworth,1992)*
Texture	Low sphericity Angular grains Moderately sorted No preferred grain orientation
Porosity	Intergranular porosity Porosity reduced by infilling of clay minerals between grains
Compaction	No evidence of compaction High grain to grain contact

4.6.5 OUTCROP 5

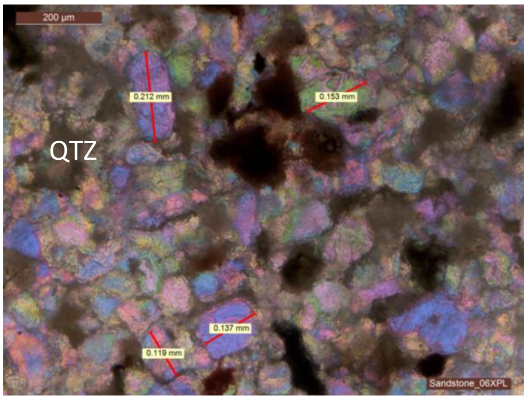
	
Plain polarised light (PPL)	Cross polarised light (XPL)

Features	**Comment**
Rock type	Chert
Grain size	0.0625 mm – 0.125 mm Very fine sand – fine sand *Based on Udden-Wenworth grain-size classification scheme (Wenworth,1992)*
Texture	Low sphericity Angular grains Moderately sorted No preferred grain orientation
Porosity	Intergranular porosity Porosity reduced by infilling of clay minerals between grains
Compaction	No evidence of compaction High grain to grain contact

4.6.6 OUTCROP 6



Plain polarised light (PPL)



Cross polarised light (XPL)

Features	Comment
Rock type	Sandstone
Grain size	0.125 mm – 0.25 mm Fine sand – medium sand *Based on Udden-Wenworth grain-size classification scheme (Wenworth,1992)*
Texture	Low sphericity Angular grains Moderately sorted No preferred grain orientation
Porosity	Intergranular porosity Porosity reduced by infilling of clay minerals between grains
Compaction	No evidence of compaction High grain to grain contact

4.7 TECTONO – STRATIGRAPHIC EVOLUTION OF SEMANGGOL FORMATION

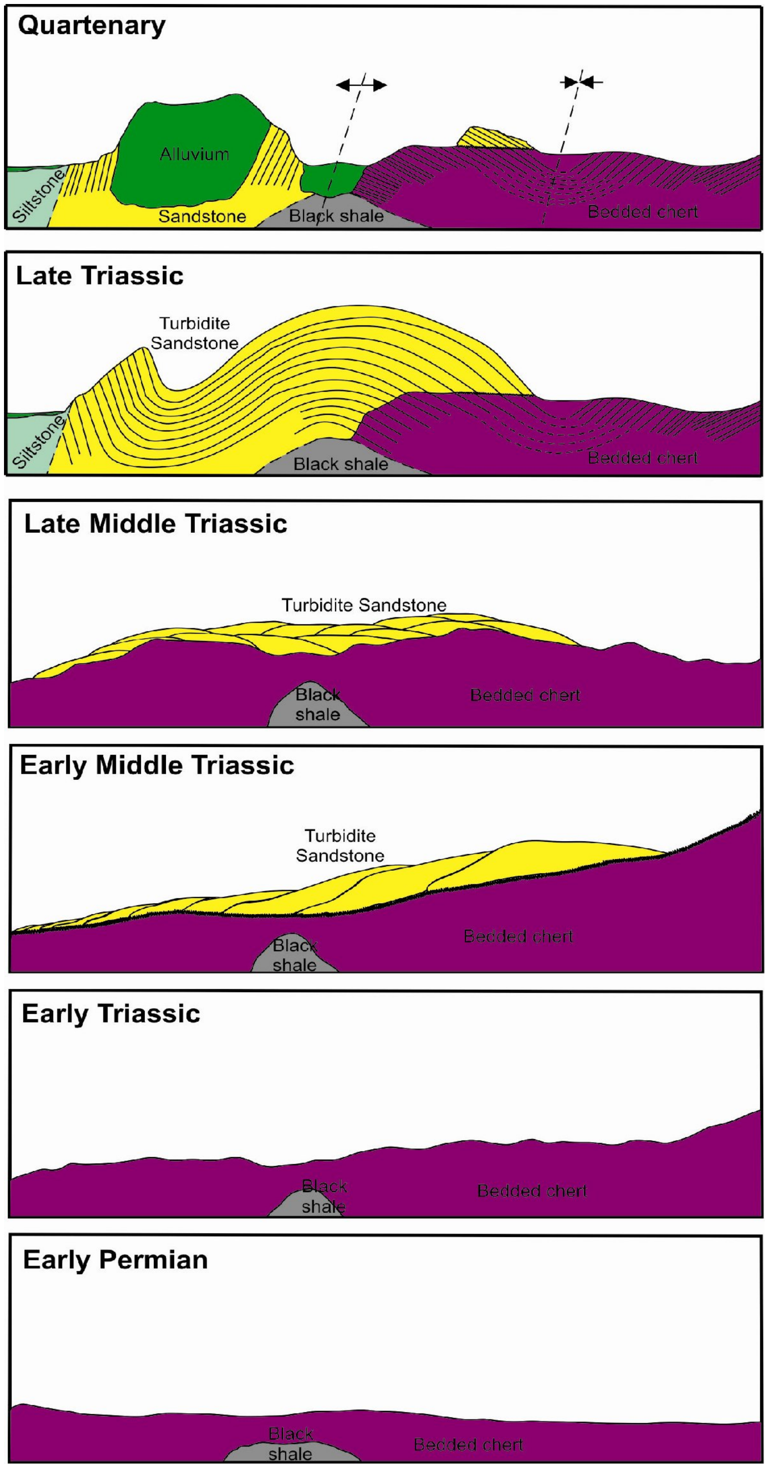


Figure 4.32: Tectono-stratigraphic model of northern Gunung Semanggol

Peninsular Malaysia is composed of Sibumasu and East Malaya – Indochina terranes. The Sibumasu continental lithospheric terrane formed the west of Bentong-Raub Suture. On the other hand, the eastern part of Peninsular Malaysia is the East Malaya-Indochina terranes. This terrane is bounded to the west by Nan-Uttaradit-Sra Kaeo and Bentong-Raub sutures in Thailand and Malaysia respectively and to the northeast by Song Ma suture zones.

These continental blocks formed part of India-Australia margin of Gondwana in the Lower Palaeozoic. The floras and faunas of the Sibumasu block have resemblance to Gondwana until Early Permian (Sakmarian). In addition, the presence of Early Permian glacial-marine diamictites associated with cold climate give evidence that Sibumasu block was still connected to Gondwana up until Early Permian. Due to the separation and northwards drift of the terrane, by Asselian-Sakmarian the floras and faunas have become warm climate Cathaysian types. On the other hand, Indochina block has drifted earlier from Gondwana, during Devonian. Ordovician and Silurian floras and faunas of Indochina show Gondwana affinities, however during Late Carboniferous these similarities are no longer recorded.

The Bentong-Raub suture zones embody the Palaeo-Tethys Ocean which opened in the Devonian. Devonian was a period of growth for the Palaeo-Tethys Ocean. Subduction of Palaeo-Tethys begun in Carboniferous with evidence of volcanic arcs, as some areas along the Bentong-Raub Suture has been identified to have Late Palaeozoic volcanic arcs. This process is then followed by subduction of Palaeo-Tethys beneath Indochina during Permian and continued until Triassic. This subduction processes closed the ocean beneath Sibumasu and Indochina. This resulted in the destruction of the ocean, followed by collision of the two continental blocks, forming what is called Indosinian orogeny complex. This tectonic episode terminated deep ocean deposits of Peninsular Malaysia. In the Triassic, turbiditic rhythmite and conglomerate of the Semanggol Formation were deposited in the Semanggol foredeep basin on top of Permian and Triassic cherts.

These tectonic events affected the formation and sediments deposition of Gunung Semanggol. It is suggested that bedded chert is deposited first, possibly during Early Permian when the deep marine settings, below Calcite Compensation Depth (CCD) contributed to settling of silica minerals on the ocean bottom. Siliciclastic sediments eventually prograded over the chert and turbidite and infilled the Semanggol basin This is proved by deposition of turbidite materials, as seen at Outcrop 4,5 and 6, interbedded of sandstone and siltstone and shale. In addition, it is important to take note that black shale are found at Outcrop 3, that might suggest that these rocks may be older than the Permian bedded chert, possibly Devonian-Carboniferous when black shale is abundant during that period.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Preliminary results acquired support the researches and studies done by previous workers. Northern Gunung Semanggol is from Early Permian to Late Triassic age based on radiolarian biostratigraphy. The lithology of the outcrop is predominantly bedded chert, sandstone interbedded with shale and siltstone. The basal cherts, coarse grained sandstone with interbedded shale are interpreted as deepwater marine sediments. Structural analysis shows orientation in N-S direction folds in Gunung Semanggol area, due to the East-West collision of Sibumasu Semanggol basin with Indochina-East Malaya tectonic block, which also generated the Bintang/Titiwangsa granite along the major suture zone. Detailed observation on the sedimentary and stratigraphic succession of the outcrop suggests that the northern Gunung Semanggol may has been deposited between middle to outer submarine fan, mainly on the channel margin.

The improved geological model presented in this project can be used as analogue / reference in future works. Other than that, other aspects of methodology such as geochemistry and palaeontology could be considered in further study to accurately differentiate the Permian and Triassic rocks should be conducted. Finally, extra safety precautions from moving vehicles need to be taken as most of the outcrops are along road cuts.

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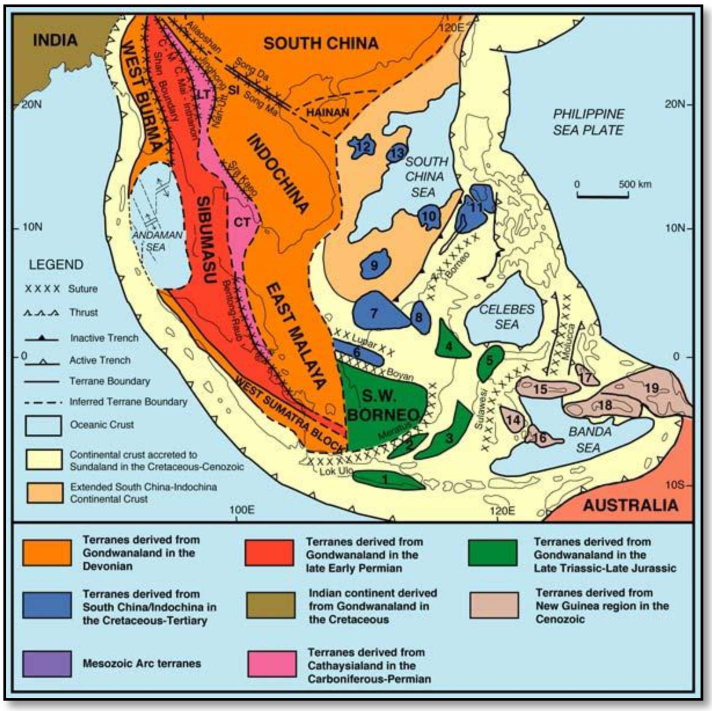
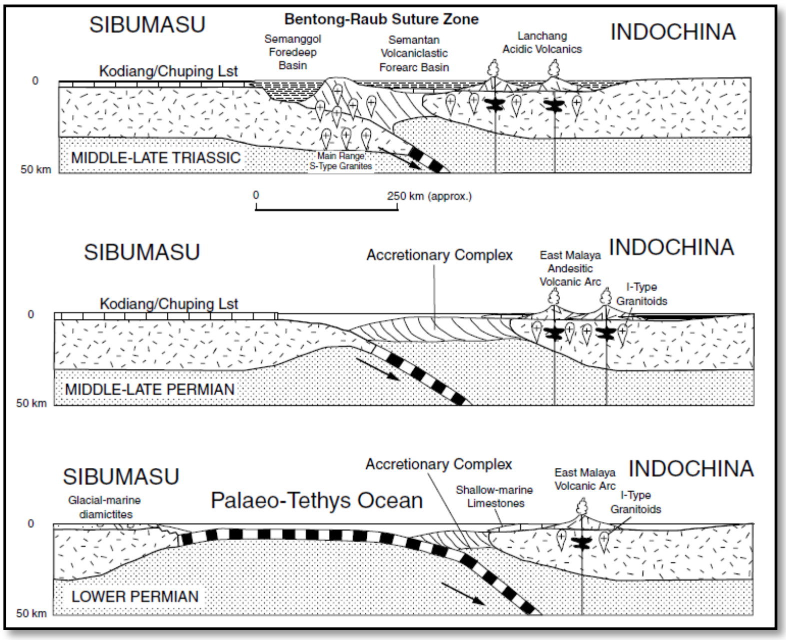
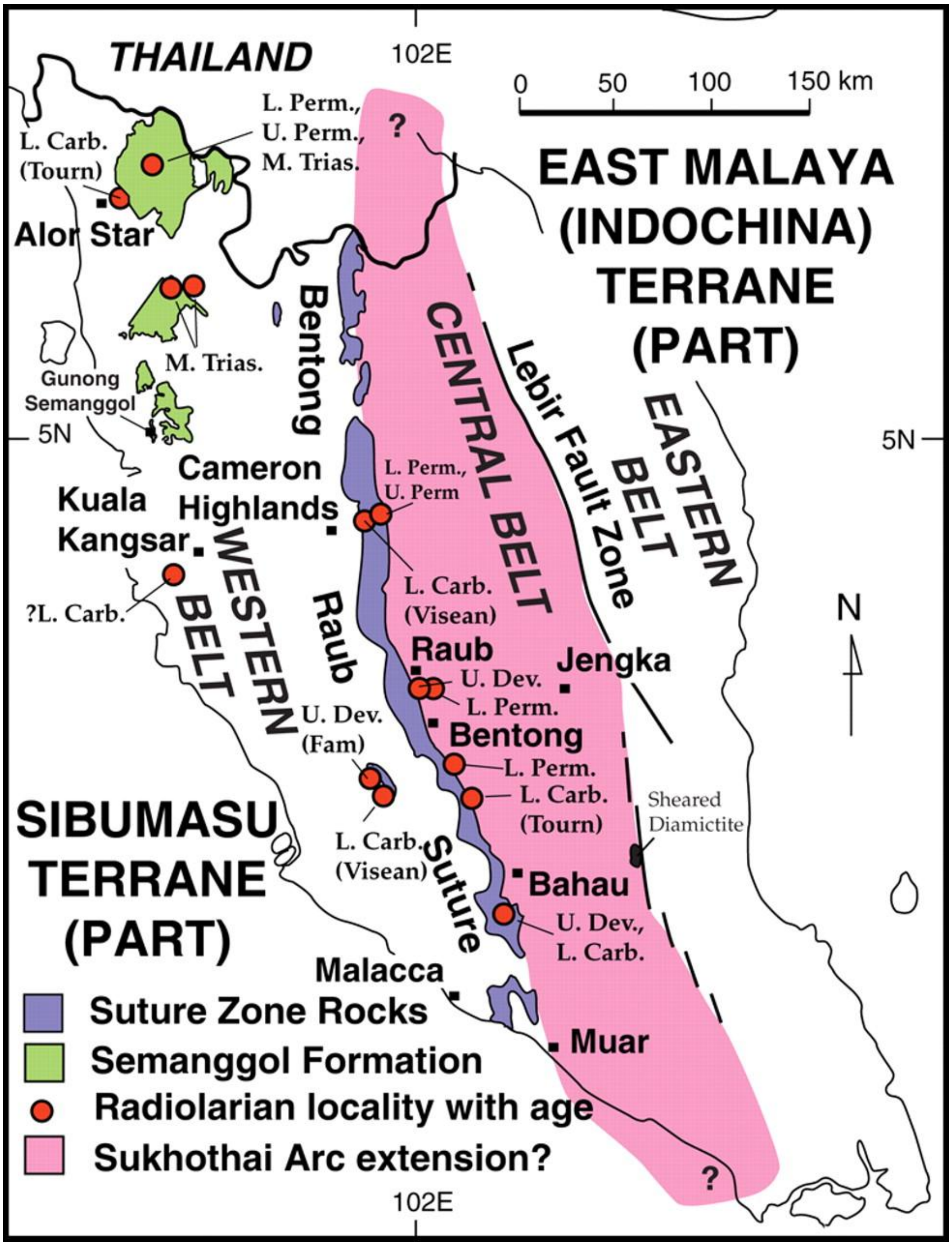
APPENDICES



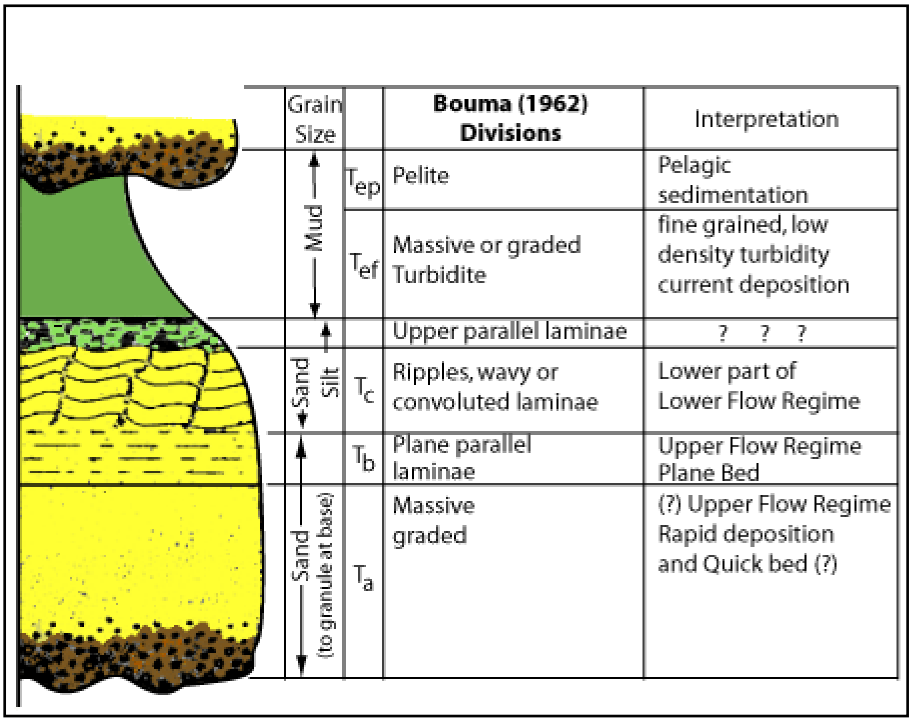
Appendix 1: Distribution of continental clocks and terranes of Southeast Asia



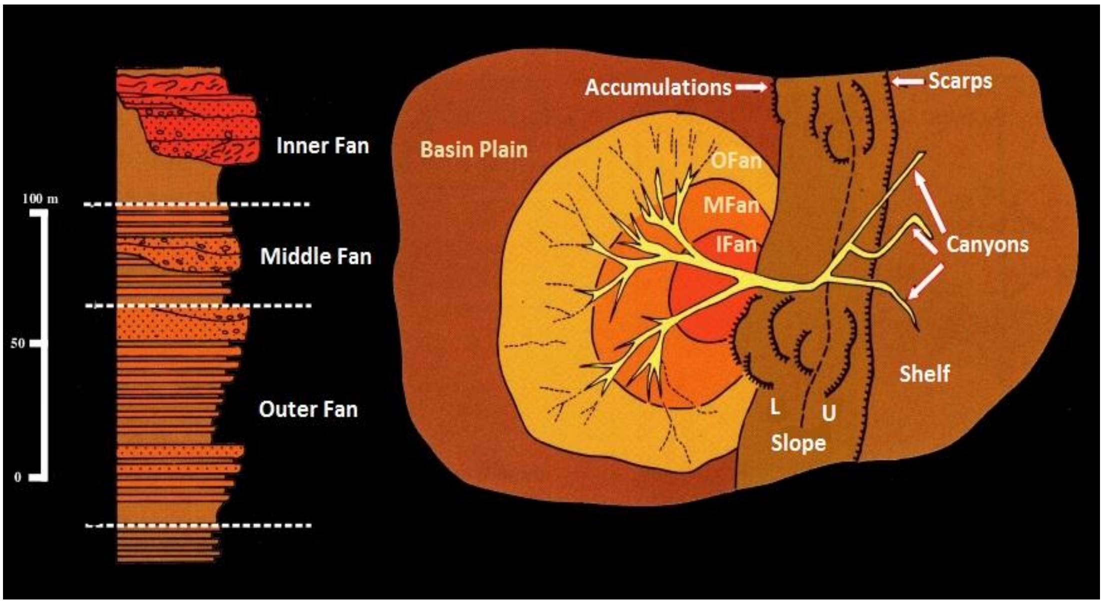
Appendix 2: Formation of Bentong-Raub suture by collision of Sibumasu block with Indochina block



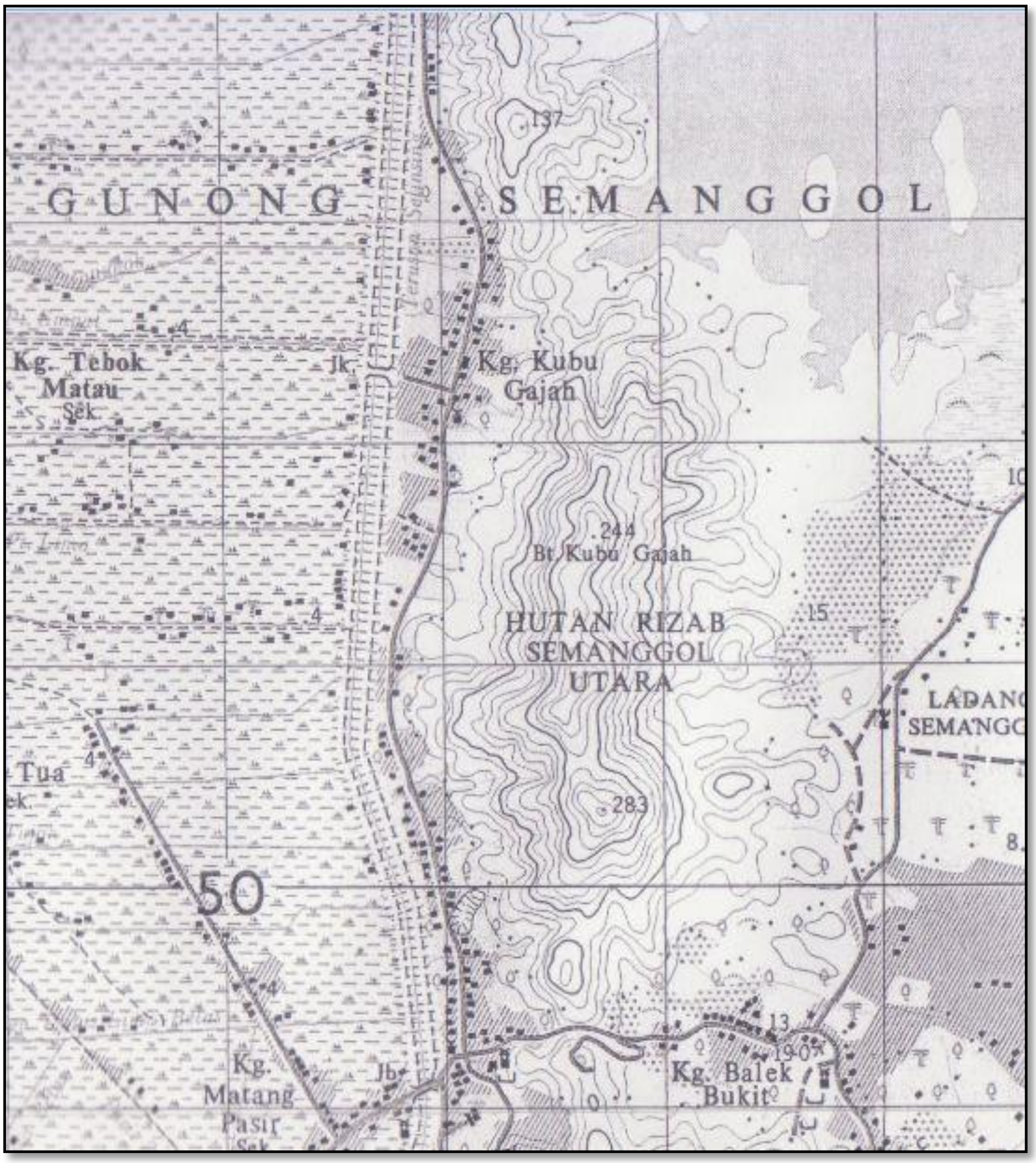
Appendix 3: Distribution of rocks in West, Central and East belt of Peninsular Malaysia. Radiolarian locality and age are also shown.



Appendix 4: Bouma sequence explaining turbidite model



Appendix 5: Sub-marine fans model and associated sedimentary log (Mutti & Luchi, 1972)



Appendix 6: Topography map (Sheet 3364) of northern Gunung Semanggol

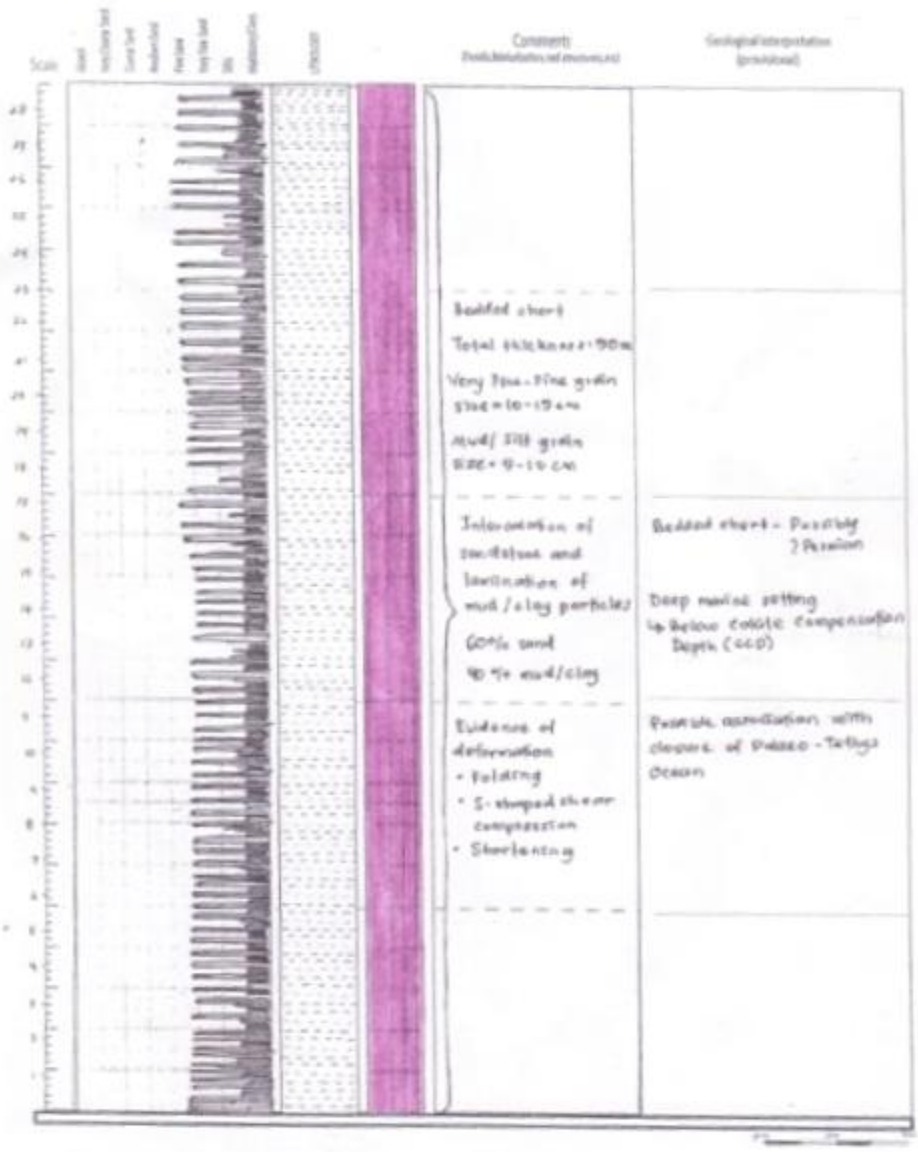
Appendix 7: Bedded chert with shale lamination in between at Outcrop 1

Appendix 8: Front view of bedded chert (bottom) and sandstone body (top) observed at Outcrop 3

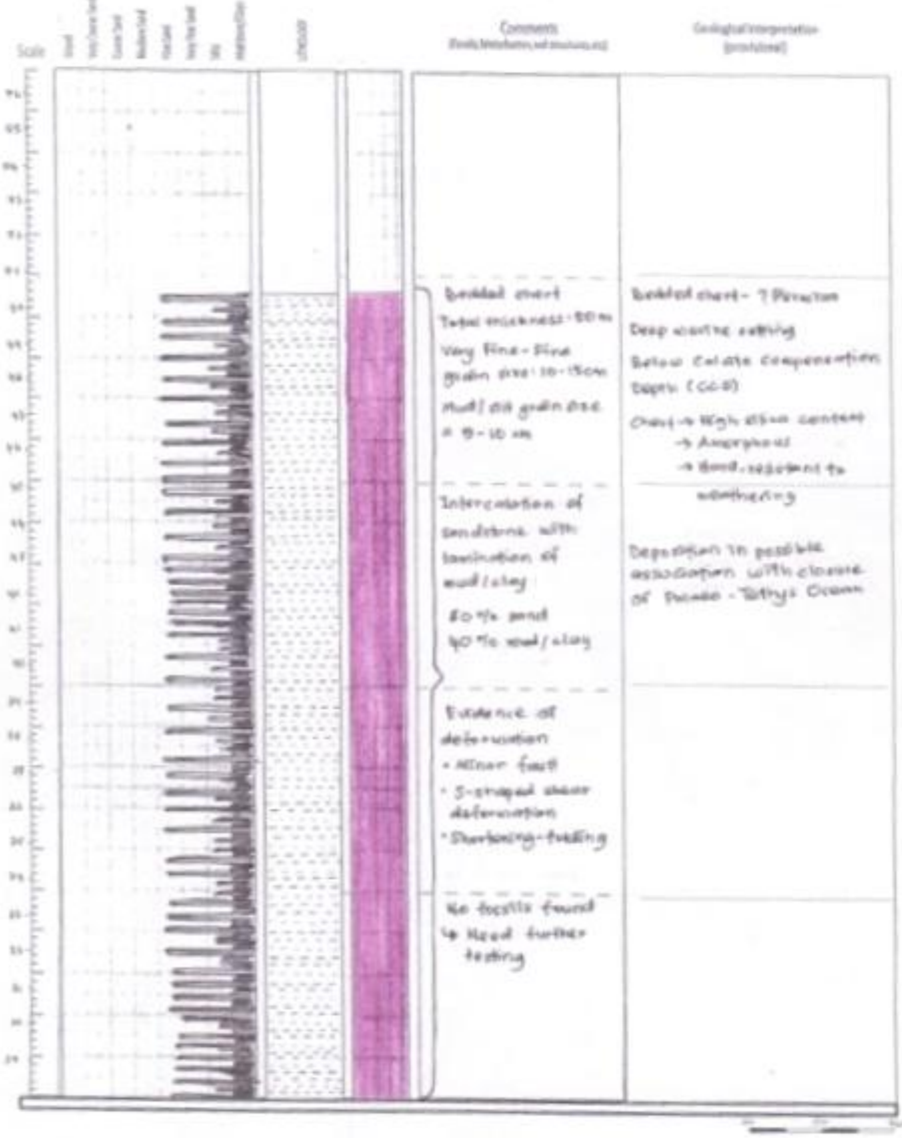
Appendix 9: Panorama view of middle fan sequences at Outcrop 4

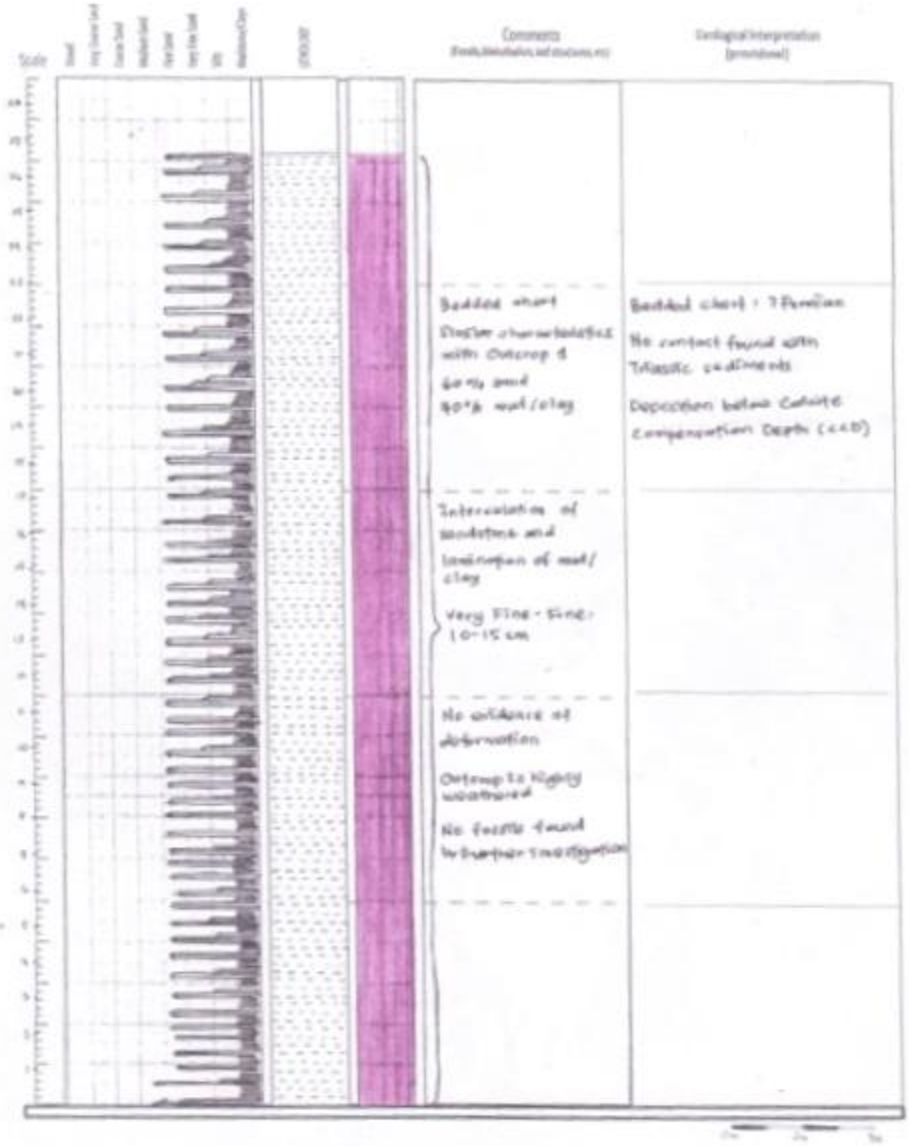
Appendix 10: Sandstone interbedded with siltstone and shale laminae at Outcrop 5

Appendix 11: Nearly vertical sandstone ridges at Outcrop 6

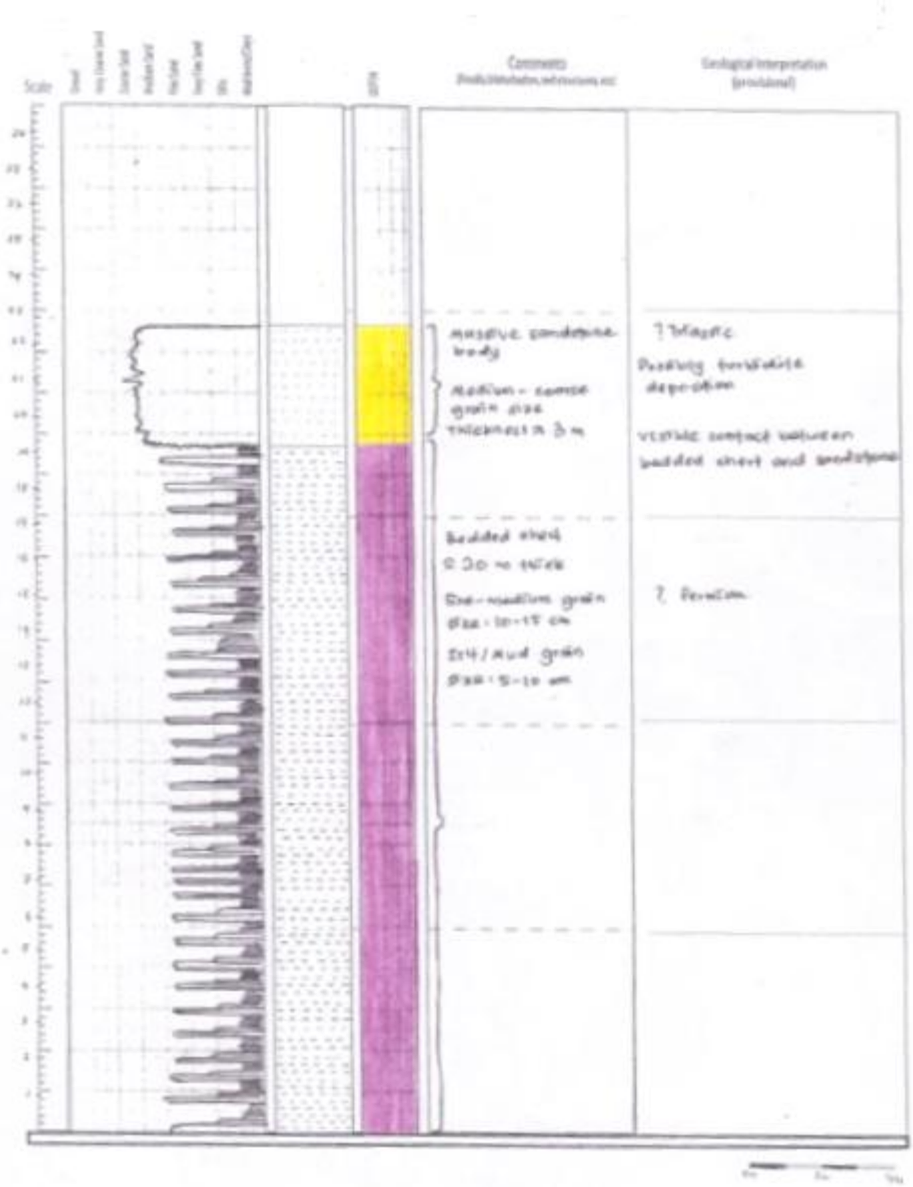


Appendix 12: Sedimentary log of Outcrop 1 (continued)

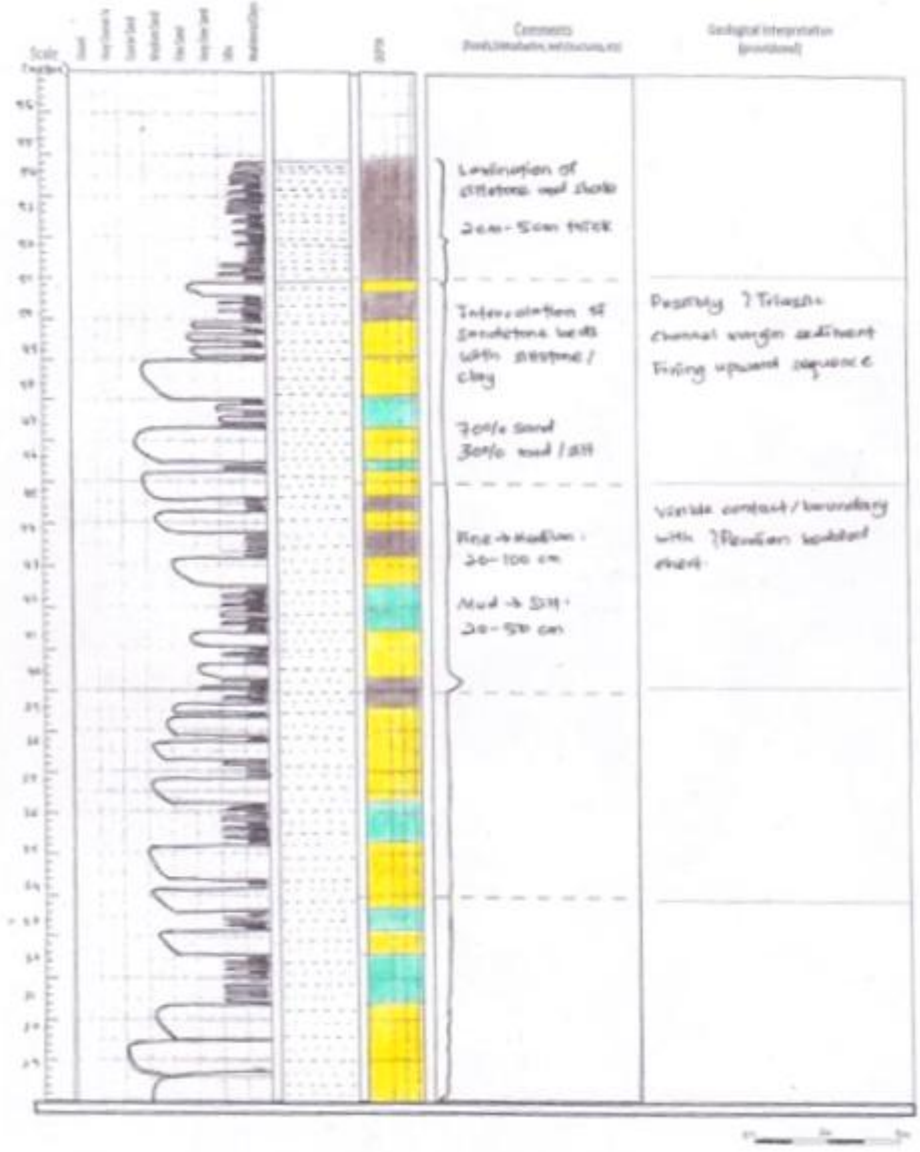




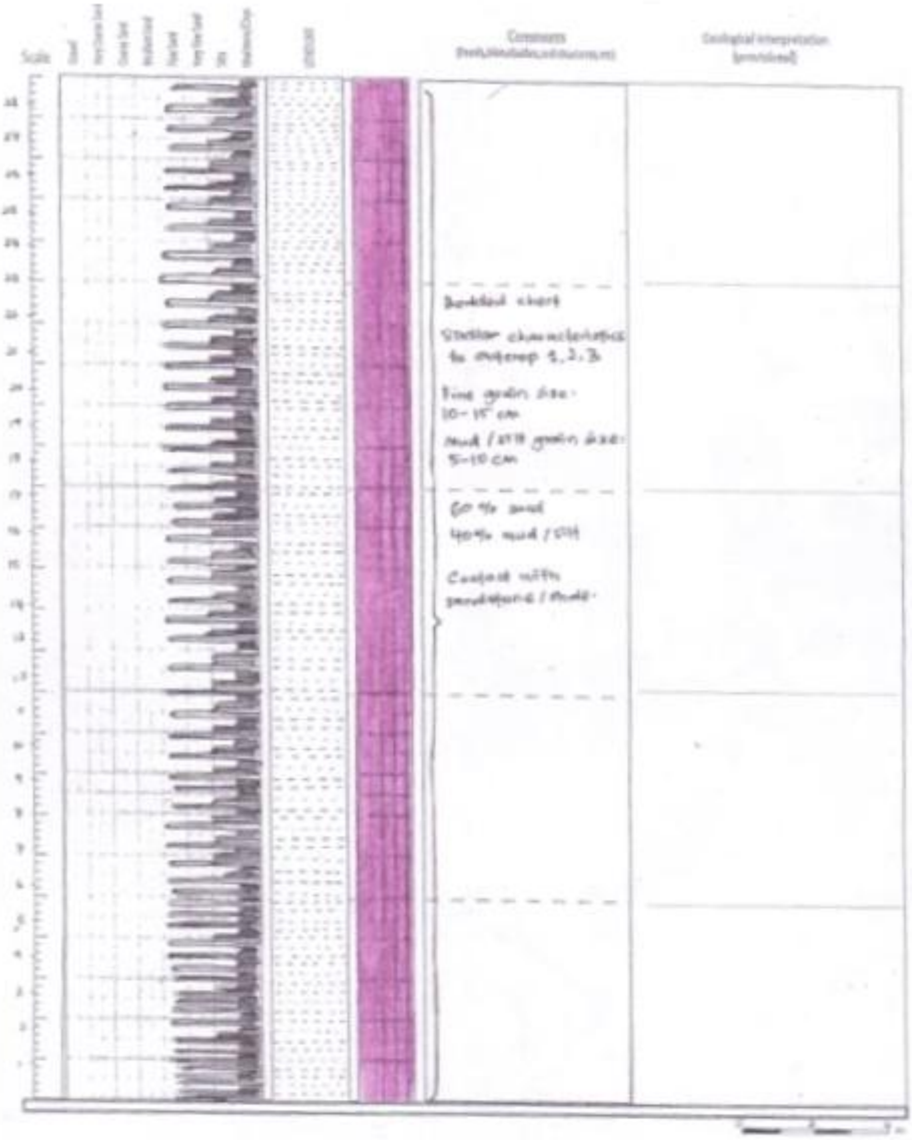
Appendix 13: Sedimentary log of Outcrop 2

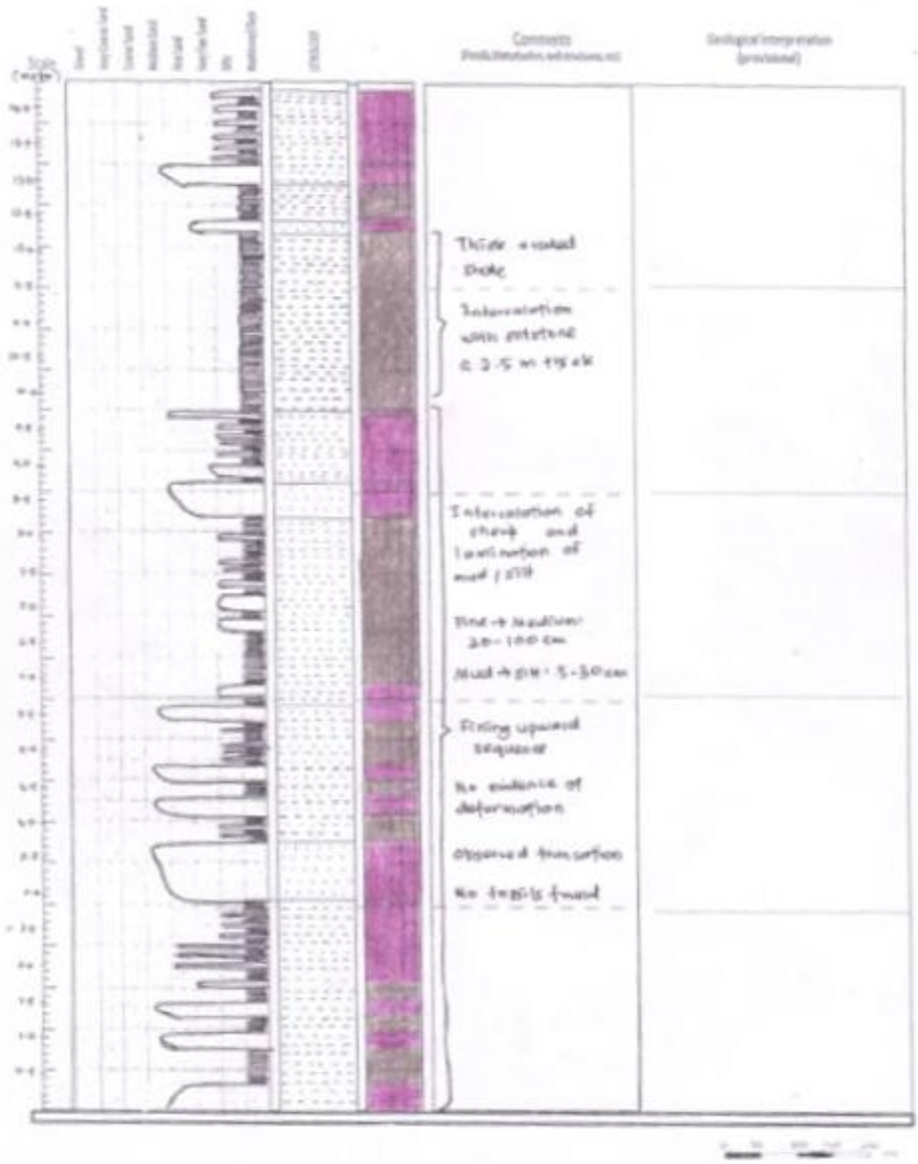


Appendix 14: Sedimentary log of Outcrop 3

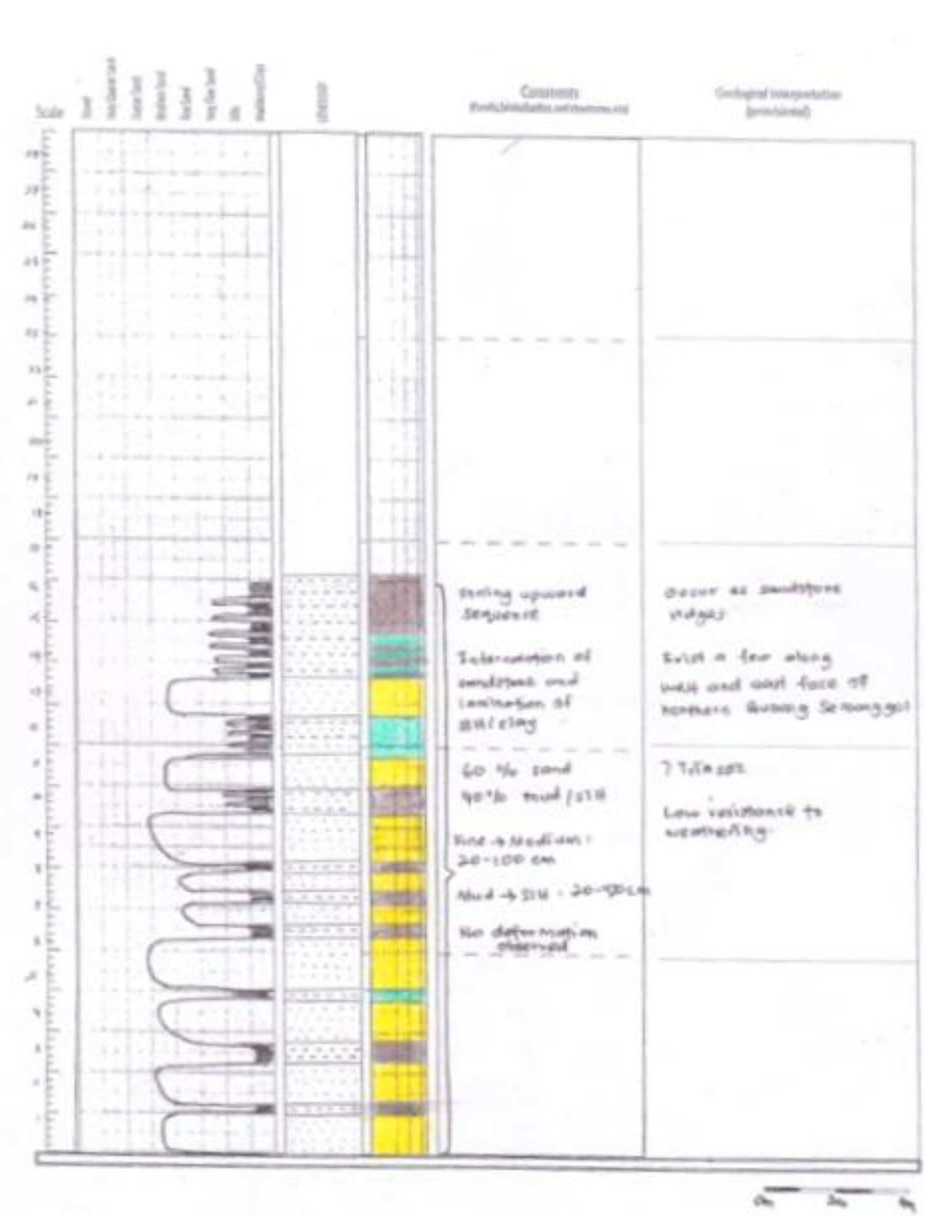


Appendix 15: Sedimentary log of Outcrop 4 (continued)


Scale
Comments
Geological interpretation
Bedded chert
Similar characteristics to outcrop 1,2,3
Fine grain size: 10-15 cm
Mud / silt grain size: 5-10 cm
60 % sand
40% mud / silt
Contact with sandstone / mud.



Appendix 16: Sedimentary log of Outcrop 5



Appendix 17: Sedimentary log of Outcrop 6

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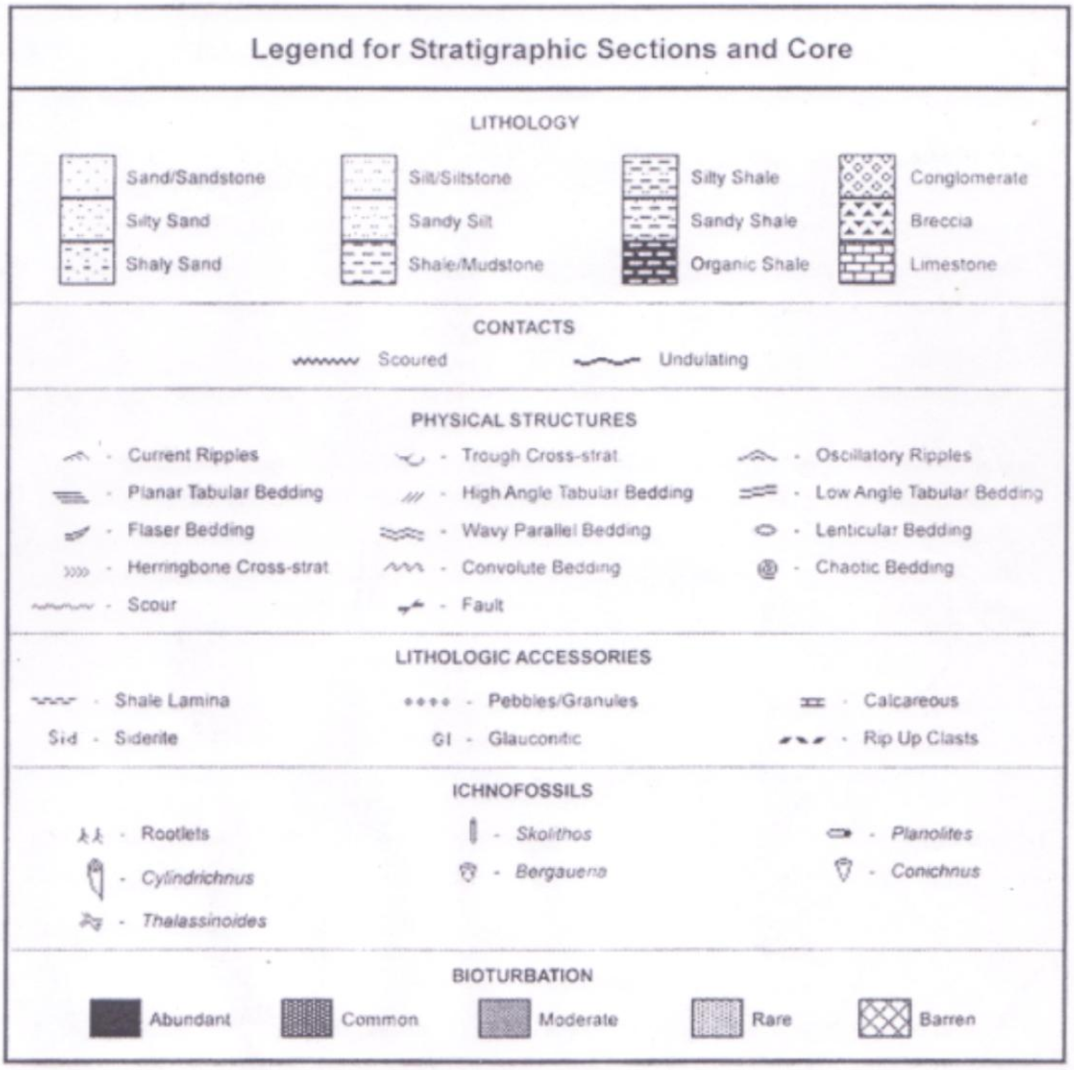

Appendix 18: Legend used in sedimentary log

Appendix 19: Strike and dip reading measured at each outcrops

Strike and dip reading of Outcrop 1

GPS Coordinate: N 04^0 58' 17.86'' E 100^0 39' 54.51''

NO	STRIKE	DIP	NO	STRIKE	DIP
1	SE 165^0	40^0 W	**30**	SE 176^0	52^0 W
2	SE 165^0	40^0 W	**31**	SE 173^0	52^0 W
3	SE 163^0	41^0 W	**32**	SE 169^0	51^0 W
4	SE 163^0	40^0 W	**33**	SE 169^0	54^0 W
5	SE 161^0	49^0 W	**34**	SE 172^0	50^0 W
6	SE 160^0	43^0 W	**35**	SE 171^0	55^0 W
7	SE 161^0	45^0 W	**36**	SE 172^0	46^0 W
8	SE 162^0	42^0 W	**37**	SE 170^0	51^0 W
9	SE 159^0	42^0 W	**38**	SE 174^0	47^0 W
10	SE 164^0	44^0 W	**39**	SE 174^0	41^0 W
11	SE 166^0	47^0 W	**40**	SE 173^0	43^0 W
12	SE 166^0	53^0 W	**41**	SE 172^0	46^0 W
13	SE 169^0	49^0 W	**42**	SE 172^0	49^0 W
14	SE 170^0	49^0 W	**43**	SE 168^0	47^0 W
15	SE 170^0	51^0 W	**44**	SE 176^0	42^0 W
16	SE 175^0	50^0 W	**45**	SE 177^0	42^0 W
17	SE 173^0	44^0 W	**46**	SE 176^0	48^0 W
18	SE 174^0	43^0 W	**47**	SE 177^0	54^0 W
19	SE 172^0	41^0 W	**48**	SE 174^0	56^0 W
20	SE 171^0	56^0 W	**49**	SE 167^0	53^0 W
21	SE 171^0	56^0 W	**50**	SE 173^0	47^0 W
22	SE 175^0	53^0 W	**51**	SE 173^0	49^0 W
23	SE 175^0	54^0 W	**52**		
24	SE 175^0	45^0 W	**53**		
25	SE 175^0	45^0 W	**54**		
26	SE 175^0	44^0 W	**55**		
27	SE 175^0	46^0 W	**56**		
28	SE 175^0	49^0 W	**57**		

Strike and dip reading of Outcrop 2

GPS Coordinate: N 04^0 58’ 8.04’’ E 100^0 39’ 58.87’’

NO	STRIKE	DIP	NO	STRIKE	DIP
1	SE 172^0	40^0 W	**30**	SE 176^0	52^0 W
2	SE 175^0	40^0 W	**31**	SE 173^0	52^0 W
3	SE 169^0	41^0 W	**32**	SE 169^0	51^0 W
4	SE 171^0	40^0 W	**33**	SE 169^0	54^0 W
5	SE 171^0	49^0 W	**34**	SE 172^0	50^0 W
6	SE 176^0	43^0 W	**35**	SE 171^0	55^0 W
7	SE 171^0	45^0 W	**36**	SE 172^0	46^0 W
8	SE 172^0	42^0 W	**37**	SE 170^0	51^0 W
9	SE 178^0	42^0 W	**38**	SE 174^0	47^0 W
10	SE 174^0	44^0 W	**39**	SE 174^0	41^0 W
11	SE 173^0	44^0 W	**40**	SE 173^0	43^0 W
12	SE 176^0	53^0 W	**41**	SE 172^0	46^0 W
13	SE 179^0	49^0 W	**42**	SE 172^0	49^0 W
14	SE 170^0	49^0 W	**43**	SE 168^0	47^0 W
15	SE 170^0	51^0 W	**44**	SE 176^0	42^0 W
16	SE 175^0	50^0 W	**45**	SE 177^0	42^0 W
17	SE 173^0	44^0 W	**46**	SE 176^0	48^0 W
18	SE 174^0	43^0 W	**47**	SE 177^0	54^0 W
19	SE 172^0	41^0 W	**48**	SE 174^0	56^0 W
20	SE 171^0	56^0 W	**49**	SE 167^0	53^0 W
21	SE 171^0	56^0 W	**50**	SE 173^0	47^0 W
22	SE 175^0	53^0 W	**51**	SE 173^0	44^0 W
23	SE 175^0	54^0 W	**52**	SE 173^0	44^0 W
24	SE 175^0	45^0 W	**53**	SE 175^0	50^0 W
25	SE 175^0	45^0 W	**54**	SE 165^0	40^0 W
26	SE 170^0	44^0 W	**55**	SE 174^0	47^0 W
27	SE 173^0	46^0 W	**56**		
28	SE 175^0	49^0 W	**57**		
29	SE 173^0	49^0 W	**58**		

Strike and dip reading of Outcrop 3

GPS Coordinate: N 04^0 57’ 53.6’’ E 100^0 39’ 37.92’’

NO	STRIKE	DIP	NO	STRIKE	DIP
1	NE 5	65^0 E	**30**	NE 7	61^0 E
2	NE 5	65^0 E	**31**	NE 7	59^0 E
3	NE 5	64^0 E	**32**	NE 8	61^0 E
4	NE 6	65^0 E	**33**	NE 8	62^0 E
5	NE 6	66^0 E	**34**	NE 5	59^0 E
6	NE 5	65^0 E	**35**	NE 9	62^0 E
7	NE 4	64^0 E	**36**	NE 6	62^0 E
8	NE 5	63^0 E	**37**	NE 3	65^0 E
9	NE 6	68^0 E	**38**	NE 2	64^0 E
10	NE 3	65^0 E	**39**	NE 2	67^0 E
11	NE 3	68^0 E	**40**	NE 1	65^0 E
12	NE 5	67^0 E	**41**	NE 2	67^0 E
13	NE 4	67^0 E	**42**	NE 3	66^0 E
14	NE 7	65^0 E	**43**	NE 4	66^0 E
15	NE 7	65^0 E	**44**	NE 5	65^0 E
16	NE 8	66^0 E	**45**		
17	NE 5	64^0 E	**46**		
18	NE 8	62^0 E	**47**		
19	NE 7	64^0 E	**48**		
20	NE 4	63^0 E	**49**		
21	NE 6	61^0 E	**50**		
22	NE 5	62^0 E	**51**		
23	NE 3	63^0 E	**52**		
24	NE 3	61^0 E	**53**		
25	NE 5	67^0 E	**54**		
26	NE 4	66^0 E	**55**		
27	NE 5	62^0 E	**56**		
28	NE 6	62^0 E	**57**		
29	NE 4	63^0 E	**58**		

Strike and dip reading of Outcrop 4

GPS Coordinate: N 04^0 0’ 0.92’’ E 100^0 39’ 18.16’’

NO	STRIKE	DIP	NO	STRIKE	DIP
1	SE 175^0	55^0 W	**30**	SE 171^0	53^0 W
2	SE 175^0	55^0 W	**31**	SE 171^0	51^0 W
3	SE 174^0	54^0 W	**32**	SE 173^0	51^0 W
4	SE 172^0	55^0 W	**33**	SE 174^0	56^0 W
5	SE 173^0	53^0 W	**34**	SE 173^0	55^0 W
6	SE 175^0	55^0 W	**35**		
7	SE 175^0	57^0 W	**36**		
8	SE 176^0	56^0 W	**37**		
9	SE 177^0	55^0 W	**38**		
10	SE 175^0	52^0 W	**39**		
11	SE 174^0	53^0 W	**40**		
12	SE 178^0	52^0 W	**41**		
13	SE 177^0	55^0 W	**42**		
14	SE 176^0	54^0 W	**43**		
15	SE 174^0	58^0 W	**44**		
16	SE 175^0	58^0 W	**45**		
17	SE 177^0	52^0 W	**46**		
18	SE 177^0	55^0 W	**47**		
19	SE 175^0	55^0 W	**48**		
20	SE 173^0	54^0 W	**49**		
21	SE 172^0	56^0 W	**50**		
22	SE 172^0	54^0 W	**51**		
23	SE 173^0	54^0 W	**52**		
24	SE 175^0	56^0 W	**53**		
25	SE 177^0	55^0 W	**54**		
26	SE 176^0	53^0 W	**55**		
27	SE 176^0	53^0 W	**56**		
28	SE 175^0	54^0 W	**57**		
29	SE 174^0	52^0 W	**58**		

Strike and dip reading of Outcrop 5

GPS Coordinate: N 04^0 58' 12.8'' E 100^0 39' 42.7''

NO	STRIKE	DIP	NO	STRIKE	DIP
1	SE 155^0	40^0 W	**26**	SE 168^0	35^0 W
2	SE 159^0	24^0 W	**27**	SE 168^0	37^0 W
3	SE 156^0	27^0 W	**28**	SE 170^0	40^0 W
4	SE 160^0	29^0 W	**29**	SE 171^0	38^0W
5	SE 159^0	29^0 W	**30**	SE 171^0	38^0 W
6	SE 168^0	29^0 W	**31**	SE 177^0	35^0 W
7	SE 168^0	25^0 W	**32**	SE 177^0	35^0 W
8	SE 165^0	25^0 W	**33**	SE 178^0	60^0 W
9	SE 166^0	23^0 W	**34**	SE 178^0	58^0 W
10	SE 166^0	22^0 W	**35**	SE 178^0	57^0 W
11	SE 160^0	22^0 W	**36**	SE 179^0	40^0 W
12	SE 159^0	23^0 W	**37**	SE 179^0	44^0 W
13	SE 161^0	20^0 W	**38**	SE 177^0	46^0 W
14	SE 158^0	25^0 W	**39**	SE 168^0	55^0 W
15	SE 161^0	9^0 W	**40**	SE 168^0	50^0 W
16	SE 110^0	10^0 W	**41**	SE 167^0	54^0 W
17	SE 170^0	10^0 W	**42**	SE 177^0	60^0 W
18	SE 177^0	18^0 W	**43**	SE 177^0	59^0 W
19	SE 177^0	22^0 W	**44**	SE 171^0	38^0 W
20	SE 178^0	25^0 W	**45**	SE 170^0	39^0 W
21	SE 178^0	24^0 W	**46**	SE 168^0	63^0 W
22	SE 162^0	23^0 W	**47**	SE 168^0	65^0 W
23	SE 161^0	24^0 W	**48**	SE 169^0	65^0 W
24	SE 173^0	33^0 W	**49**	SE 161^0	40^0 W
25	SE 167^0	33^0 W	**50**	SE 160^0	43^0 W

NO	STRIKE	DIP	NO	STRIKE	DIP
51	SE 177^0	46^0 W	**76**	SE 177^0	50^0 W
52	SE 176^0	56^0 W	**77**	SE 179^0	50^0 W
53	SE 177^0	64^0 W	**78**	SE 178^0	50^0 W
54	SE 175^0	66^0 W	**79**	SE 177^0	46^0 W
55	SE 172^0	60^0 W	**80**	SE 176^0	49^0 W
56	SE 171^0	63^0 W	**81**		
57	SE 174^0	52^0 W	**82**		
58	SE 175^0	54^0 W	**83**		
59	SE 171^0	59^0 W	**84**		
60	SE 171^0	57^0 W	**85**		
61	SE 175^0	52^0 W	**86**		
62	SE 176^0	52^0 W	**87**		
63	SE 179^0	53^0 W	**88**		
64	SE 177^0	49^0 W	**89**		
65	SE 178^0	45^0 W	**90**		
66	SE 178^0	52^0 W	**91**		
67	SE 179^0	54^0 W	**92**		
68	SE 177^0	53^0 W	**93**		
69	SE 177^0	48^0 W	**94**		
70	SE 177^0	49^0 W	**95**		
71	SE 178^0	49^0 W	**96**		
72	SE 177^0	54^0 W	**97**		
73	SE 178^0	52^0 W	**98**		
74	SE 179^0	51^0 W	**99**		
75	SE 179^0	50^0 W	**100**		

Strike and dip reading of Outcrop 6

GPS Coordinate: N 04^0 57' 59.49'' E 100^0 39' 13.44''

NO	STRIKE	DIP	NO	STRIKE	DIP
1	SE 177^0	85^0 W	**30**	SE 175^0	86^0 W
2	SE 177^0	83^0 W	**31**		
3	SE 175^0	86^0 W	**32**		
4	SE 173^0	86^0 W	**33**		
5	SE 176^0	87^0 W	**34**		
6	SE 176^0	89^0 W	**35**		
7	SE 178^0	85^0 W	**36**		
8	SE 179^0	84^0 W	**37**		
9	SE 180^0	85^0 W	**38**		
10	SE 180^0	86^0 W	**39**		
11	SE 176^0	82^0 W	**40**		
12	SE 176^0	83^0 W	**41**		
13	SE 174^0	83^0 W	**42**		
14	SE 175^0	84^0 W	**43**		
15	SE 174^0	85^0 W	**44**		
16	SE 170^0	86^0 W	**45**		
17	SE 173^0	87^0 W	**46**		
18	SE 172^0	87^0 W	**47**		
19	SE 171^0	84^0 W	**48**		
20	SE 171^0	82^0 W	**49**		
21	SE 169^0	85^0 W	**50**		
22	SE 171^0	85^0 W	**51**		
23	SE 174^0	88^0 W	**52**		
24	SE 174^0	89^0 W	**53**		
25	SE 177^0	90^0 W	**54**		
26	SE 177^0	90^0 W	**55**		
27	SE 178^0	88^0 W	**56**		
28	SE 178^0	81^0 W	**57**		
29	SE 176^0	85^0 W	**58**		